

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

Report of the
TWENTY-SEVENTH SOUTHERN PASTURE AND FORAGE CROP
IMPROVEMENT CONFERENCE

University of Georgia
Athens, Georgia 30601

July 15-16, 1970

AND

Contributed Papers of Work Groups Meeting
in Conjunction with SPFCIC
July 14, 1970

Southern Forage Breeders' Group
Southern Forage Physiology and Ecology Work Group
Southern Forage Extension Work Group

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Crops Research Division

TABLE OF CONTENTS

	<u>Page</u>
SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE, July 15, 1970...	1
Introduction.....	1
Future of Forages in Animal Production--A. A. Hanson.....	2
Physiological Factors in the Management of Forage Plants-- Richard H. Hart.....	12
Symposium: The Disposition of Nutrients in the Soil-Plant-Animal Cycle Under Pasture Conditions	
Sources, Levels, Losses, and Availability of Nitrogen in Soils-- Grant W. Thomas.....	15
Sources, Levels, Losses, and Availability of Mineral Elements in Soils--Warren B. Anderson.....	26
Utilization of Nitrogen and Minerals by Forage Plants-- E. M. Evans.....	31
Removal of Soil Nutrients by Grazing Animals--R. S. Lowery (no paper submitted)	
The Fate of Nutrients in the Excreta of Grazing Animals-- W. W. Woodhouse, Jr.....	35
Committee Reports:	
Pre-Conference Executive Committee Meeting.....	37
Report of Forage Evaluation Committee.....	38
Report of Resolutions Committee.....	39
SPFCIC General Business Meeting.....	40
SPFCIC Executive Committee Meeting.....	40
SOUTHERN FORAGE BREEDERS' GROUP, July 14, 1970.....	42
Cytoplasmic Male Sterility--John R. Edwardson.....	42
Application of Male Sterility to Forage Legume Breeding-- R. R. Smith.....	47

SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE
July 15, 1970

C. L. Mondart, Jr , Chairman

INTRODUCTION

Opening Session:

The Twenty-seventh meeting of the Southern Pasture and Forage Crop Improvement Conference was opened by Conference Chairman, C. L. Mondart, Jr. Chairman Mondart introduced all present by States and agency (organizations); he announced a business meeting for SPFCIC this afternoon at termination of work session. Chairman Mondart appointed a Nominations Committee of H. D. Ellzey, J. D. Burns, and John E. Moore, Chairman. The committee report is due this afternoon at the business meeting. He appointed a Resolutions Committee of T. H. Taylor, J. H. Reynolds, and C. Y. Ward, Chairman. This report is due the night of the banquet.

Future of Forages in Animal Production

A. A. Hanson
USDA, ARS, Crops Research Division
Beltsville, Maryland

This topic is peculiarly appropriate for discussion in the United States. As McCloud (9) indicated, "No other country feeds much grain to beef animals for fattening." It is also significant to note that, on a world-wide basis, there is no clear evidence that the heavy dependence of meat and milk production on forages is apt to shift in the years ahead.

Perhaps the greatest potential for increasing livestock production occurs in the tropics, which now support some 60 percent of the world's cattle and 50 percent of the sheep and goats (7). There, improvement will depend very largely on increasing the quality and yield of tropical pastures. Research and action programs will center on the introduction and development of superior adapted grasses and legumes, improved fertilization practices, weed and brush control, economical forage conservation practices, together with the control of animal diseases and parasites and livestock improvement. Many examples could be cited to show the tremendous benefits that can accrue from improved forage production practices in tropical regions. The carrying capacity and rate of gain on three adapted grasses in central Brazil are shown in Table 1 to illustrate progress that can be achieved through the use of better grasses (13).

In the United States, the annual value of forages in livestock production has been placed at \$8 billion, which is about equal to the cash receipts from cotton, soybeans, wheat, tobacco, and rice (6). This valuation does not include the very substantial contribution of perennial grasses and legumes to soil stabilization, water yield and quality, wildlife numbers, and various recreational activities. In 1965, according to Hodgson, forages provided more than half the feed units consumed by livestock, with dairy cattle obtaining two-thirds and beef cattle three-fourths of their feed units from this source (Table 2). The types and proportion of forages consumed by different classes of dairy animals are shown in Table 3.

Since World War II there has been a sharp decline in dairy cattle numbers and a corresponding growth in beef cattle numbers (Table 4). In the period from 1950 to 1966, milk cow numbers decreased by about 33 percent while average milk production per cow increased 57 percent. The consumption of concentrates by cattle are summarized in Table 5. These figures show very clearly that, within the framework of present technology and available forage quality, higher, more profitable levels of milk production per cow has required liberal grain feeding.

Hodgson suggests that the change in proportion of cattle on feed to other beef cattle (Table 4) reflects in part the trend toward moving cattle into feed lots at lighter weights. On the other hand, it is readily apparent that the amount of concentrates fed to beef cattle on a per head basis (Table 5) has remained relatively constant over the two decades shown. We must remember,

however, that the trend toward marketing beef animals at lighter weights has increased the relative importance of concentrates in beef feeding programs.

We have been exposed to a wide range of forecasts and predictions on the future of forages in the U.S. The very frequency of these talks and reports are symptomatic of growing concern over the direction of forage use, forage research priorities, and the uncertainty associated with current animal production practices. Available forecasts on the future of forages provide us with opinions ranging from highly optimistic to highly pessimistic. This divergence in opinion can be accounted for by the time span involved in projections and by the natural predilection of authors to view the national scene in terms of local and regional trends. All reports on this topic suffer from two major shortcomings; namely, inadequate census data on the current value of forages, especially pasture and range, and the lack of comparative data on the economics of alternative feeding systems. The low relative gains in hay yields in comparison with other crops (Table 6) have received attention in most analyses, together with hay harvesting and storage losses (Table 7).

There is no reason to expect that my views should carry any more weight than those expressed by others. The same inadequate information has been available to anyone who feels compelled to make predictions. It is simply a question of examining current trends, polishing a very cloudy crystal ball, and speaking in glorious generalities. If this is so, perhaps we should not try too hard to uncover future trends and future problems. We can retreat from the unknown and make our case in terms of the 1 billion acres of grasslands in the United States. Who can deny on the basis of acreage alone that what's good for forage is good for the country! Unfortunately, this is an untenable position because of the limited resources available for forage research and the urgency to devote these resources to high-priority problems. Changes in the traditional role of forages in animal production must be examined to the best of our ability if we are to use our research resources to advantage.

The role of forages in animal production, however, cannot be divorced from the future of farm animals in a world where the human population is increasing at an alarming rate. It is essential, therefore, that we consider the consequences of projections that would place world population at 6.9 billion by the year 2000. Ewell (3) concludes that, in the absence of organized birth control or wide-spread starvation or nuclear war, the world population might exceed 7 billion by 2000 A.D. Obviously, world agriculture will have to double production during the next 30 years or so, and further increases will be required to improve existing levels of nutrition (8). It is argued that when man reaches this point in time he will be unable to afford meat, simply because animals devour more protein in the form of plant food than they produce in the form of meat (11). Some authorities have condemned livestock as a "wasteful intermediary" in which the relative efficiency for converting protein from cereals and oilseeds into milk and meat protein is about 10 to 25 percent, respectively (10).

Moore et al. (10) have drawn attention to the fallacious reasoning embodied in some of these analyses. They feel, and rightly so, that insufficient attention is given to the capacity of ruminants to convert feed other than cereals and oilseeds, such as forages, into protein for human consumption.

It is apparent that the conversion of plant proteins to meat and milk has not been adjusted to reflect the very substantial contribution of feeds not suited for direct human consumption, namely, forages, byproducts of food manufacturing, crop residues, and such nonprotein nitrogen sources as urea. Moore and his associates cite a Wisconsin survey of 1,500 dairy cows in 46 herds in which the total protein input had been corrected for crops and crop byproducts inedible to humans. On this basis, 96 percent of the protein in their cereal and oilseed rations was returned as milk protein (Table 8). It was also shown that the use of urea at recommended levels would have returned 376 pounds of milk protein from only 272 pounds of protein from cereals and oilseeds. This represents a 40 percent increase in protein production by combining cereals and oilseeds with forages and urea.

A second flaw in some reasoning is that man and animals are incompatible. An examination of the "sacred cow" myth provides an interesting insight into the relationships that can exist between ruminant animals and man. Protected by Hindu taboo from being slaughtered and eaten, these supposedly useless animals wander about impeding traffic and, it is reported, damaging crops. In some parts of India, aged cattle are housed in bovine old-age homes. The large number of animals and inefficiency of the dairy industry lend support to U.S. and Indian sponsored reports which claim that the large animal population is more a liability than an asset, in view of limited land resources (Table 9). Conversely, Harris (5) concludes that the rate at which cattle are slaughtered in India will be governed by the ability of the peasantry to accomplish this without impairing the production of traction animals, fuel, fertilizer, and milk. Any large scale increase in animal slaughter before traction, fuel, and manure needs of the productive cycle are met by other means would jeopardize the lives of tens of millions of Indians. Harris characterizes the sacred cow as "an exploited scavenger, a mere walking skeleton for most of the year, because her ecological niche is removed from that of human food crops." He stresses the continued need for bullocks, the value of 800 million tons of dung produced annually with 500 million tons used in manuring (the 300 million tons consumed as fuel is equivalent to 35 million tons of coal), the contribution of old, dry, barren animals to dung production, the production of hides which are of vital importance to traditional farming technology (6 million cattle hides produced in 1962), and to the fact that a considerable number of the 20 million bovines that die each year are eaten by untouchables, Moslems, pagans, and Christians. India does not provide a realistic view of future trends in animal production, but it does illustrate most emphatically some aspects of a noncompetitive relationship that can exist between man and ruminant livestock.

There are good reasons to expect that animal protein will continue to make a large and valuable contribution to world protein supplies, irrespective of the status of cereal and oilseed crops in animal feeding systems. In many countries, the feeding of ruminants would undergo little or no change with increasing human demand for plant protein. As stated previously, substantial gains in yield of animal protein could be achieved throughout the tropics with almost any improvement in forage production and animal health. In the United States significant changes in animal feeding practices would accompany a marked reduction in the availability of feed grains and oilseeds. It would

become essential to devote much greater attention to the efficient production and conservation of forages, to the utilization of processed crop residues, and to the use of urea as a replacement for plant proteins (2, 10, 14). Technology is, in fact, available to support very large increases in animal numbers and animal protein production. We can find these data in many forage production experiments and from practical farm operations (2). Additional encouragement can be found in the energy available in cereals, straw, and cornstalks. Thus, it has been estimated on the basis of total digestible nutrients that by 1980 the straw and stover from grain production could maintain 49 million dairy cows producing 9,900 pounds of milk per cow per year (10). However, attaining animal production goals in the absence or near absence of concentrates will require additional research to improve the quality and persistence of forages, to improve efficiency in conserving and feeding forages, and to improve quality and reduce costs of collecting and processing crop residues.

Although we may be tempted to accept these dramatic changes in animal-feeding practices as inevitable, I seriously doubt that this extreme situation will prevail in the United States neither in the immediate future nor for many years to come. My reasoning is based on assumptions as to the probable course of population growth in the United States and on the probable nature of this country's contribution in providing assistance to protein-deficient countries. There is good evidence from developed countries that population growth can be reduced very dramatically and possibly stabilized at levels where technology can maintain and improve the standard of living. Japan and the countries of western and eastern Europe with annual birth rates in the range of 13 to 20 per thousand are well on the way to achieving this goal. Hungary has a birth rate of 13 per thousand and a death rate of 9 per thousand. This represents a growth rate of 0.4 percent per year, which will require 175 years for the population to double. Compare this increase with that in Costa Rica where the birth rate is 50 per thousand, the death rate 8 per thousand, and the annual growth rate 4.2 percent per year. Continuation of this rate of growth would double the population in 16 years (3).

These comparisons lead me to conclude that we can succeed in reducing the rate of population increase in the United States and by so doing maintain a high standard of living. Under these circumstances, animal protein could continue to provide about two-thirds of the protein requirements in American diets.

The food crisis in less developed countries, where 80 percent of the world's population will reside by the year 2000, is the second variable that demands our attention in the United States. Some people feel that the expanded production of food crops for export will reduce supplies and increase costs of feed grains and oilseed crops for animal production. Equally compelling arguments can be made for increasing the export of animal protein that has the added benefits of iron, niacin, riboflavin, and B₁₂. The export of animal protein may well be encouraged by price relationships and the demand to upgrade the quality of plant proteins. Depending on export demand, we could continue to feed animals large quantities of plant protein from cereals and oilseeds and obtain a large net return in animal protein. As mentioned, the

net gain in animal protein would result from feeding noncompeting feedstuffs--forages, food industry byproducts, crop residues, and nonprotein nitrogen.

In the immediate future, confinement feeding will remain important for both beef and dairy production. The advantages enjoyed by large commercial feedlots include the production of relatively uniform animals, a near continuous flow of slaughter-grade animals, and efficient use of labor. Disadvantages include disease and pollution problems, as well as lack of control over the price of purchased feeds. On the other hand, confinement feeding may not be the most efficient method for producing lower-grade, lean beef. Grass fattening of beef can supplement confinement feeding and provide much of the expansion in production needed by the year 2000 and beyond. The following trends in animal production can be expected to prevail:

- 1) Emphasis will continue on finishing choice and prime cattle in feedlots on "all concentrate" rations. Most of these rations will include varying amounts of dehydrated forage to increase the efficiency of urea utilization and to provide growth factors and roughage (1). See also Table 10.

- 2) Vigorous attempts will be made to reduce feeding costs in commercial feedlots. This might involve reduction in the degree of finish and time animals are on feed, and somewhat greater use of competitive processed forages.

- 3) Locally, corn silage and alfalfa hay will remain important, but there is little likelihood of an immediate shift toward heavier forage feeding in commercial feedlots.

- 4) Greater emphasis will be given to the production of grass-fattened cattle, some of which could be marketed at 12 months or less. Many of the feeding systems will be based on spring and early summer pasture, limited winter supplementation of fall-dropped nursing calves, and limited energy supplementation on early spring pasture. Depending on the region, grass-fattening programs will make provision for either high quality, annual summer pasture, or restricted feeding of nonprotein nitrogen supplements to animals on perennial forages.

- 5) Grass-fattened beef will be highly competitive for use in manufactured meat products and as a source of lean cut meat from carcasses grading high good.

- 6) Improved grass-fattening programs will provide greater flexibility to many traditional producers of feeder cattle. Comparatively small beef units, possibly operating under contract, could be highly competitive in producing certain grades of beef.

- 7) An increase in cow-calf operations can be anticipated on grain farms to meet the demand of commercial feedlots. Feeding programs would be based on improved pasture, silage, crop residues, and urea (4).

- 8) Current technology is such that one cannot predict any major changes in the dairy industry other than a continuing shift to large commercial herds.

Large milk producers will continue to rely very heavily on concentrates and silage with minimal amounts of hay and little or no pasture.

9) Hay and pasture will remain important on smaller dairy units and in the production of replacement heifers.

10) In the absence of appropriate advances in technology, hay will retain its current level of importance only in those areas where soil and climatic conditions favor high yields and comparatively low harvesting losses or preclude the economical production of competitive feed crops.

11) Field processing of hay into wafers, cubes, and pellets will expand in areas where climatic conditions are favorable, with a concomitant increase in the use of these products in beef and dairy cattle rations.

12) Dehydrated alfalfa and grasses will have an important and expanding role in the manufacture of feed supplements, formula feeds, and "all concentrate" rations.

Advances in technology might lead to significant changes in these predictions and include a brighter outlook for hay production, a stronger case for confinement feeding in cow-calf operations, etc. However, current research inputs suggest that forage-animal relationships will follow the pattern outlined. Forages will continue to occupy an important place in animal production, but, as noted, the relative importance of various forages will be influenced by production costs, the availability and price of competing feedstuffs, and by changes in animal-feeding systems.

This is not the place to restate either the objectives of forage research or the role of intensive interdisciplinary research in attaining these objectives. Most of us are all too aware of the urgent need to reduce seeding failures, improve yields and persistence, secure effective levels of multiple pest resistance, increase herbage quality, as well as tolerance to drought, extreme temperatures, and unfavorable soil conditions. I will simply conclude my remarks by mentioning a few areas that deserve attention in the light of projected trends in animal production.

We should pay more attention to identifying species that exhibit the greatest potential for improvement and within which improved varieties would offer the best promise for increasing the flexibility of animal feeding systems.

We need to reevaluate the role of pastures and range in reducing the cost of animal production; we need to redirect our attention to selecting grasses and legumes, including productive hay species, for tolerance to intensive grazing and for their response to improved soil fertility.

We must realize that the supplementation of grazing animals does not reduce the need for improving herbage quality. Improvements in intake and digestibility can lower animal production costs, and there is a critical need to improve the quality of accumulated pasture herbage.

We must be concerned with improving the yield and quality of perennial legumes and grasses specifically adapted for the production of processed forage products. There is a similar need to improve the quality of productive, persistent species that are little used because of poor animal acceptance and performance.

Literature Cited

1. Beeson, W. M. 1966. Future trends in beef and sheep production. Proc. Amer. Dehy. Assoc. January.
2. Burton, Glenn W. 1966. Let's re-examine forage value. Plant Food Review (Fall), pp. 2-4.
3. Ewell, Raymond. 1966. Population outlook in developing countries. The Role of Animal Agriculture in Meeting World Food Needs. Proc. Agr. Res. Inst., Washington, D.C., October, pp. 10-11.
4. Garst, David. 1964. Cows and calves on a feed grain farm. Proc. Amer. Grassland Council, 1963-64, pp. 103-107.
5. Harris, Marvin. 1967. The myth of the sacred cow. Natural History LXXVI(3):6-12.
6. Hodgson, H. J. 1968. Forages--their present importance and future potentials. Agr. Sci. Rev. 6(2):23-30.
7. Hutton, E. M. 1968. Tropical and sub-tropical grassland research. Agr. Sci. Rev. 6(4):7-17.
8. Irving, G. W. 1969. Trends in animal agriculture. Presentation at the annual meeting of the Animal Health Institute, Arlington, Va., April 22. Mimeo.
9. McCloud, Darell E. 1965. Grassland agriculture for the future. Proc. Second National Grassland Field Day and Conference, Univ. of Tenn., pp. 49-54.
10. Moore, L. A., P. A. Putnam, and N. D. Bayley. 1967. Ruminant livestock--their role in the world protein deficit. Agr. Sci. Review 5(2):1-8.
11. Paarlberg, D. 1966. The potential impact on animal agriculture of a changing U.S. policy as a result of the world's food population ratio. Nat. Inst. of Animal Agr., Purdue Univ.
12. Pope, L. S. 1969. Impact of changing patterns in the beef industry. Feedstuffs, May 24, p. 8.
13. Quinn, L. R. C., G. O. Mott, W. V. A. Bisschoff, M. B. Jones, and G. L. Da Rocha. 1965. Beef production of six tropical grasses in central Brazil. Proc. Ninth Intern. Grassland Congr. 2:1015-1020.

14. Walsh, Leo M. 1966. 600 million forgotten acres? Plant Food Review (Fall), 5-6, 15.

Table 1. Beef Production in Central Brazil (Quinn et al., 1965)

Grasses	Steer Days/A	Avg. Daily Gain (Lbs.)	Beef Lbs/A (Liveweight)
Guinea	191	0.98	182
Pangola	246	0.80	214
Molasses	116	0.77	81

Table 2. Percentage of Feed Units From Concentrates and Forage Consumed by Livestock, 1965 (Hodgson, 1968)

	Concentrates	Forages
All livestock	47	53
Dairy cattle	34	66
Beef cattle	22	78
Sheep and goats	11	82
Horses and mules	22	78

Table 3. Forages as Percentage Consumption of All Feeds (Expressed as Feed Units) by all Dairy Animals in the United States, 1965

Class	Other Harvested		Pasture	Total
	Hay	Forage		
Milk cows	28	16	18	62
Other dairy cattle	31	7	46	84
All dairy cattle	29	14	25	68

Table 4. Populations of Dairy and Beef Cattle^{1/} (Hodgson, 1968)

	1949	1959	1966
Milk cows	23.8	19.5	15.2
Other dairy	12.6	11.0	7.7
Cattle in feed ^{2/}	6.5	13.1	22.0
Other beef	35.1	58.1	64.1

^{1/} Millions^{2/} Number fed during year

Table 5. Consumption of Concentrates by Cattle, Per Head, by Pounds (Hodgson, 1968)

	1949	1959	1966
Milk cows	1,558	2,495	3,279
Other dairy	458	628	699
Cattle on feed	2,399	2,191	2,455
Other beef	185	195	220

Table 6. Changes in Yield per Acre of Selected Crops

Crop	Unit	1954	1965	% Incr.
Corn grain	Bu.	37.1	73.1	100
Sorghum grain	Bu.	19.0	50.1	164
Barley	Bu.	28.5	43.5	53
Soybeans	Bu.	20.1	24.4	21
Corn silage	Ton	7.5	10.6	41
Alfalfa, alfalfa mix.	Ton	2.1	2.48	18
Clover, timothy mix.	Ton	1.43	1.53	7

Table 7. Effect of Harvesting Loss on Hay Costs

	Harvesting and Storage Loss (%)			
	30	20	10	0
Net yield/A (tons)	2.30	2.64	2.98	3.30
Cost/ton (\$)	24.00	20.83	18.46	16.67

Table 8. Protein Inputs-Outputs From Cereals and Oilseeds in a Dairy Cow Operation^{1/} (Moore et al., 1967)

Source of Input	Crude Protein (lbs.)	
	Input	Output in Milk
3,166 lbs. of grain and oilseed concentrates/yr.	381	376

^{1/} Cows producing 11,649 lbs. milk containing 3.69% butterfat

Table 9. Estimated Cattle Population in India (1961)

	Million
Cows	79.4
Milk producers	20.1 (avg. prod/cow 413 lbs.)
Bullocks	96.3
Working animals	68.6

Table 10. Daily Feed Requirements for 10,000 Head Feedlot^{1/}
(Pope, 1969)

Processed grain	84 tons
Protein supplement	10 tons
Molasses	6 tons
Salt, mineral, additives	1 ton
Dry roughage equivalent	19 tons
Total Daily Feed	120 tons

^{1/} Assuming 700 lb. yearling consumes 24 lbs. of feed/day

Physiological Factors in the Management of Forage Plants

Richard H. Hart
USDA, ARS, Crops Research Division
Beltsville, Maryland

Forage management practices are seldom based on knowledge of plant physiology. We have based our recommendations on empirical tests of seeding dates, fertilizer rates, and height and frequency of clipping. We have done this partly from ignorance, because we did not know enough plant physiology; partly from laziness, because physiological research is hard work; and partly from bitter experience, because management practices that seemed physiologically sound didn't work in the field. However, a survey of pasture experiments being conducted in 1938 shows we are still doing the same kind of empirical research that was being done then (14), so perhaps for the sake of novelty we should look more closely at the role of physiology.

Selection of the forage species to be grown in a particular area is based on physiological considerations, although we don't often understand the adaptive mechanisms which make it possible to grow a species in one environment and not another. We are beginning to define some of the physiological differences between tropical and temperate grasses; this may enable us to set limits to the degree of success we can expect when we move temperate plants into a tropical environment, and vice versa.

Understanding the physiology of the germinating seed and the young seedling can help increase the odds in favor of establishment Yields of tall fescue

in the year after seeding are strongly correlated with moisture conditions immediately after planting (6). Recent research has defined periods during germination when soil moisture or temperature limit emergence (1, 11). Knowledge of such critical periods can be teamed with knowledge of long-term trends in weather and short-term forecasts in planning seeding so as to avoid exposure to unfavorable conditions at the critical time.

The LAI concept is an example of misapplication of physiology to management. It seems reasonable that dry matter production is a function of the product of leaf area and photosynthetic efficiency. The trouble starts when we don't define efficiency, but use it as a "finagle factor" to make the equation come out even. Efficiency changes rapidly, reflecting changes in leaf age, leaf angle, and partitioning of dry matter between roots and tops.

Even if we could define and maintain the leaf area required for maximum dry matter production, this might not be the optimum management. If a high stubble is left to maintain a high LAI, much of the forage must remain unharvested. If a high average LAI is maintained by infrequent cutting, quality must suffer. Seasonal distribution of forage production may be shifted (2), and tiller production may be reduced so that yields in succeeding years are low.

The role of carbohydrate reserves in regrowth has never been properly defined. It appears that these reserves are utilized to a lesser extent, and for a shorter time after defoliation, than was once believed (12, 16, 17). In some cases, there was little relationship between reserve levels and regrowth (3, 13, 15). Assumptions about conditions required for accumulation of carbohydrate are being questioned (3). Regrowth in alfalfa may be determined more by the number and activity of regrowth sites than by reserves or residual leaf area (10). Winter survival and early spring growth seem to be highly correlated with carbohydrate accumulation in the fall (4), but these results are susceptible to other interpretations.

Physiology, in its broadest sense, includes the response of plants to environment. Management recommendations may be based on average performance over a sample of growing seasons, without regard to how "normal" these seasons may have been, or how departures from average conditions may affect plant response.

If we wish to study physiology and management of a forage plant under grazing, we must realize that the pattern of defoliation, regrowth, and plant morphology under grazing may be totally different from the pattern under clipping (5, 7, 8, 9).

It may be easier to apply our knowledge of physiology to plant breeding than to management. If we can determine what physiological processes have the greatest influence on yield, we may be able to select high-yielding genotypes more efficiently.

Literature Cited

1. Bleak, A. T., and W. Keller. 1969. Crop Sci. 9:296-299.
2. Clapp, J. G., Jr., D. S. Chamblee, and H. D. Gross. 1965. Crop Sci. 5:469-471.
3. Dovrat, A., and Y. Cohen. 1970. Proc. XI Intl. Grassl. Congr:552-554.
4. Fulkerson, R. S. 1970. Proc. XI Intl. Grassl. Congr:555-559.
5. Greenwood, E. A. N., and G. W. Arnold. 1968. J. Brit. Grassl. Soc. 23:144-148.
6. Hart, R. H., G. E. Carlson, and H. J. Retzer. 1968. Agron. J. 60:385-388.
7. _____ 1970. Agron. J. 62 (in press).
8. Hodgson, J. 1966. J. Brit. Grassl. Soc. 21:258-263.
9. Hodgson, J., and J. H. Ollerenshaw. 1969. J. Brit. Grassl. Soc. 24:226-234.
10. Leach, G. J. 1970. Proc. XI Intl. Grassl. Congr:562-566.
11. Murtagh, G. J. 1970. Proc. XI Intl. Grassl. Congr:574-578.
12. Pearce, R. B., G. Fissel, and G. E. Carlson. 1969. Crop Sci. 9:756-759.
13. Reynolds, J. H. 1969. Crop Sci. 9:720-723.
14. Smalley, H. R., and A. L. Brizzard. 1938. A survey of pasture experiments now being conducted in the humid regions of the United States. The Natl. Fert. Assoc., Nashville, Tenn.
15. Smith, D., and C. J. Nelson. 1967. Crop Sci. 7:130-133.
16. Smith, L. H., and G. C. Marten. 1970. Crop Sci. 10:146-150.
17. Wolf, D. D. 1967. Crop Sci. 7:317-320.

Sources, Levels, Losses, and Availability of Nitrogen in Soils

Grant W. Thomas
University of Kentucky

Sources of Nitrogen

1. Ammonium in Rocks. In many soils, ammonium originally in the parent rock is an important source of nitrogen. Work by Rich (1960) shows that some Virginia soils have as much as 6,000 lbs of nitrogen per acre as ammonium in a 4-foot profile. It is not known for certain whether the weathering of the mica and other minerals containing ammonium contributes substantially to the nitrogen pool of pasture soils, but it is a possibility in soils with high mica contents. Some data of Stevenson and Dhariwal (1959) on ammonium content of midwestern surface soils are shown in Table 1. The values are on the order of 100 ppm of nitrogen.

2. Nitrogen Fixation by Microorganisms. Atmospheric nitrogen fixed by microorganisms apparently contributes more to the nitrogen economy of pastures than does any other source. This nitrogen is particularly high when legumes are present but is appreciable even when grass alone is present in a sod. Practically nothing is known about non-symbiotic fixation in a pure stand of grass except that it does occur. An example of Kentucky data is shown in Table 2. These figures were taken from an 11-year study by Karraker et al. (1950) where sods were grown continuously in lysimeters. Similar data have been obtained by other workers (Russell, 1961).

3. Nitrate Due to Lightning. Nitrate in rainfall caused by atmospheric electrical discharge appears to be about proportional to the number of thundershowers which occur. Thus, only about 4 lbs per acre per year are gained in England, 5 lbs in New York (Russell, 1961), and 10 lbs in Kentucky (Karraker, et al., 1950). At any rate, it is a rather small contribution compared to microbiological fixation.

4. Manure. Although manure from a beef cow may contain 120 lbs of nitrogen per year, it is probable that only 25 to 33 percent of the nitrogen is actually returned to the grass (Russell, 1961). The rest of the nitrogen is either denitrified or volatilized under natural conditions. Thus, at a stocking rate of one cow per three acres, 10 to 13 lbs per acre of nitrogen would actually be returned, a rather small contribution compared to other sources.

5. Fertilizers. The amount of nitrogen supplied to pastures from fertilizers depends not only on the amount applied, but also on the soil conditions where it is applied. For example, a survey of Texas results on Coastal bermudagrass showed that recoveries of applied nitrogen ranged from 20 to 100 percent. Within a given soil, recoveries vary depending on weather, but there tends to be a larger difference between soils than between years.

Under any sort of favorable conditions, nitrogen from applied fertilizer reaches the grass as nitrate regardless of the form in which it is applied.

All that is required is a few days where the minimum temperature rises above freezing. Some unpublished data from Smith and Steen at Kentucky (Fig. 1) show this for ammonium sulfate. Unfortunately, the higher temperatures in this study coincided with rains which removed the nitrate almost as fast as it was formed, but the transformation of ammonium is striking. In general, the nitrogen from fertilizers will be found in the nitrate form until it is taken up by plants or lost from the soil.

Levels of Nitrogen

1. Nitrogen in Organic Matter. Figure 2 shows the relationship between organic matter contents of soils and total nitrogen (Buckman and Brady, 1960). Each point represents a number of samples from a state. The slope of the curve gives a value of slightly over 0.05 percent nitrogen per 1.0 percent organic matter; 1,000 lbs of nitrogen per acre for each percent organic matter. This is a good relationship to remember although, for reasons to be given later, it may not have much to do with nitrogen available to pastures.

2. Nitrate Content in Pasture Soils. Most references indicate that nitrate contents in pasture soils are very low compared to those in soils planted to row crops. A part of the reason for this is the fact that pastures are not fertilized as much as row crops are. Some evidence of ours that this is the case is given in Table 3, which shows that fescue fertilized at a rate about typical for corn had about the same level of nitrate as did a corn soil.

Karraker et al. (1950) found that when white clover or lespedeza died, a large release of nitrate occurred. This release was reflected by the high loss of nitrate by leaching from these sods, which was almost as high as for a bare soil (Table 4). We can conclude that soils in which legumes die, or in which grass sods have been highly fertilized, are apt to have reasonably high levels of nitrate in them. As with other crops, the level of nitrate in a pasture soil is the best measure of available nitrogen at a given sampling.

Losses of Nitrogen

1. Leaching of Nitrate. Losses of nitrogen as nitrate by leaching probably account for the largest disappearance of nitrogen from pasture soils. An example (Table 4) already has been given to show that fairly large losses can occur.

Work at Cornell (Lyon and Bizzell, 1936) showed that having crops on the land reduced nitrate leaching losses (Table 5), partially by reducing the amount of percolation. However, under Southeastern conditions it is probable that most of the reduction in nitrate leaching is due to nitrogen uptake by the plant rather than to reduction in percolation. The reason for this statement is shown in Figure 3 (taken from Karraker et al., 1950), which shows the losses of water in 3-month periods for a bare soil and a soil growing alfalfa. During the first 3 months of the year the losses are almost the same, and this is the part of the year when most of the nitrogen losses occur.

Nitrogen applied either to bare soil or to a dormant crop in the fall will suffer a drastic loss by spring under Southeastern conditions. Some of our results for corn experiments are shown in Table 6. Losses have been from 50 to 75 percent due to winter and spring rains.

2. Biological Denitrification. The presence of decomposable residue and excess water can cause rapid losses of nitrogen due to the use of the nitrate ion by bacteria as a source of oxygen. Although poor aeration is absolutely essential for this reaction, the presence of residue determines the speed at which it will go. An example of some unpublished results of Sookhakick at Kentucky are shown in Table 7. In a soil to which 75 ppm of nitrate nitrogen was added, essentially all was lost after only 6 days of flooding if residue was present. This effect can be expected to be serious on sods which contain a great deal of dead material, are fertilized with nitrogen in the spring, and are located on a heavy soil subject to wetness. This is the reason that nitrogen is sometimes so ineffective in wet areas of a field.

3. Volatilization of Ammonia. The loss of nitrogen from soil as ammonia gas is explained by the equation

$$\log \text{NH}_3 = -9.26 + \log \text{NH}_4 + \text{pH}$$

which says that the loss of ammonia will increase exponentially as the pH of the soil rises. Some results of DuPlessis and Kroontje (1964) for ammonia loss from a Virginia soil are shown in Figure 4. Obviously, there is danger of ammonia loss at any pH above 6. Losses of ammonia will always occur with high pH soils using any ammonium fertilizer, with urea regardless of soil pH, and with anhydrous ammonia. The best possibility of reducing the losses is to increase contact of the fertilizer with the soil.

Availability

1. Nitrogen in Organic Matter. It already has been pointed out that there is a continuous increase in the organic nitrogen of pastures (even if only grasses are present). It also has been shown that in bluegrass sod there is practically no nitrate present if it is not fertilized. Judging from the appearance and yield of unfertilized pure grass stands there is practically no available nitrogen in them, regardless of the total nitrogen present.

When this pure grass sod is tilled for renovation there is a large increase in available nitrogen. In fact, the immediate response of grass to renovation is solely due to the increased available nitrogen arising from the accelerated decomposition of organic matter after tillage. It has nothing to do with legumes. Similarly, turning under a nitrogen-deficient sod gives a nitrogen response to a row crop which follows.

Apparently the only way in which the accumulated nitrogen in pasture organic matter can be made available is by destroying the pasture. While the availability of nitrogen is high when tillage is practiced, losses are even higher. Table 8 shows a balance sheet for a plowed Canadian prairie (Russell, 1961). Apparently the losses are due to leaching, denitrification and

volatilization. This illustrates the problem of nitrogen recovery in pastures, whether they are left intact or are broken up.

2. Location of Nitrate in the Soil. Nitrate is so mobile in the soil that few people have even considered that it might be unavailable because of position. But there are at least two situations where poor availability seems to occur. The first is when nitrate is deep in the profile. We have found that there is no water removal by plant roots below 42 inches in any soil in Kentucky. In many soils there is no water removal below 24 inches. Since the nitrate which reaches the plant roots has to be taken up in the water, there will be poor uptake when nitrate is in the part of the soil where water uptake is low.

The second situation occurs when nitrate is in the dry surface soil. R. E. Phillips and I observed a striking nitrogen response in corn when it was irrigated. We found that the nitrate was extremely high before irrigation and was located right on the soil surface. After irrigation, the nitrate had moved into the soil three inches. This unavailability of surface nitrate explains the firing of corn leaves in soils high in nitrogen but under a drought stress.

A more basic study on pasture in England (Garwood and Williams, 1967) had surface-applied nitrogen and nitrogen applied through tubes at a depth of 18 inches. The results are shown in Table 9 and indicate that the nitrogen placed at 18 inches was much more available to the grass than that placed at the surface of the soil.

Summary

This paper deals with the sources, typical levels, important modes of loss, and a few aspects of nitrogen availability in pastures. It is by no means complete but is designed to present some points for discussion and further research.

Literature Cited

1. Buckman, H. O. and N. C. Brady. 1960. The Nature and Properties of Soil. MacMillan Co., New York.
2. DuPlessis, M. C. F. and W. Kroontje. 1964. The relationship between pH and ammonia equilibria in soil. Soil Sci. Soc. Amer. Proc. 28:751-754.
3. Garwood, E. A. and T. E. Williams. 1967. Growth, water use and nutrient uptake from the subsoil by grass swards. J. Agr. Sci. 69:125-130.
4. Karraker, P. E., C. E. Bortner, and E. N. Fergus. 1950. Nitrogen balance in lysimeters as affected by growing Kentucky bluegrass and certain legumes separately and together. Kentucky Agr. Expt. Sta. Bull. 557.
5. Lyon, T. L. and J. A. Bizzell. 1936. Lysimeter experiment. IV. Memoir 194. Cornell Univ. Agr. Expt. Sta.

6. Rich, C. I. 1960. Ammonium fixation by two red-yellow Podzolic soils as influenced by interlayer-Al in clay minerals. Trans. 7th Intern. Congr. Soil Sci. IV:468-473.
7. Russell, E. W. 1961. Soil Conditions and Plant Growth. Longmans, Green and Co., Ltd., London.
8. Stevenson, F. J. and A. P. S. Dhariwal. 1959. Distribution of fixed ammonium in soils. Soil Sci. Soc. Amer. Proc. 23:121-125.

TABLE 1. Naturally-Occurring NH_4 in Soils

<u>Soil</u>	<u>Condition</u>	<u>meg. NH_4/100g</u>
Elliott	Virgin Sod	0.89
	Cropped	0.94
Beecher	Virgin forest grass	0.76
	Cropped	0.67
Blount	Virgin forest	0.82
	Cropped	0.73

TABLE 2. N Fixed by Various Sods

<u>Species</u>	<u>N fixed (lbs/A,yr)</u>
Korean Lespedeza	206
White Clover	148
Alfalfa	223
Red Clover	171
White Clover and Bluegrass	103
Bluegrass	33

TABLE 3. NO₃ Found in Soils

	<u>lbs/A</u>
Fescue, Unfertilized	3.5
Fescue, Fertilized	26.2
Bluegrass, Unfertilized	5.6
Corn, Fertilized	28.0
Tobacco, Fertilized	42.0

TABLE 4. Losses of Nitrogen by Leaching

	<u>lbs/A, yr</u>
Korean Lespedeza	58
White Clover	52
Bluegrass	10
Bare Soil	74

TABLE 5. Losses of N by Percolation

<u>Soil</u>	<u>Condition</u>	<u>Percolation</u> <u>inches</u>	<u>N lost</u>
Dunkirk	Bare	24.92	69.0
	Cropped	18.70	7.8
Volusia	Bare	20.90	43.0
	Cropped	19.10	6.6

TABLE 6. NO₃ Remaining in Soil Profiles, May 26.

<u>Soil</u>	<u>N applied</u> <u>ppm</u>	<u>Time applied</u>	
		<u>November</u> <u>ppm</u>	<u>May</u> <u>ppm</u>
Stendall	80	45	99
	120	47	113
Zipp	50	22	81
	100	26	119

TABLE 7. $\text{NO}_3\text{-N}$ Losses From a Flooded Soil ($\text{NO}_3\text{-N}$ added 75 ppm)

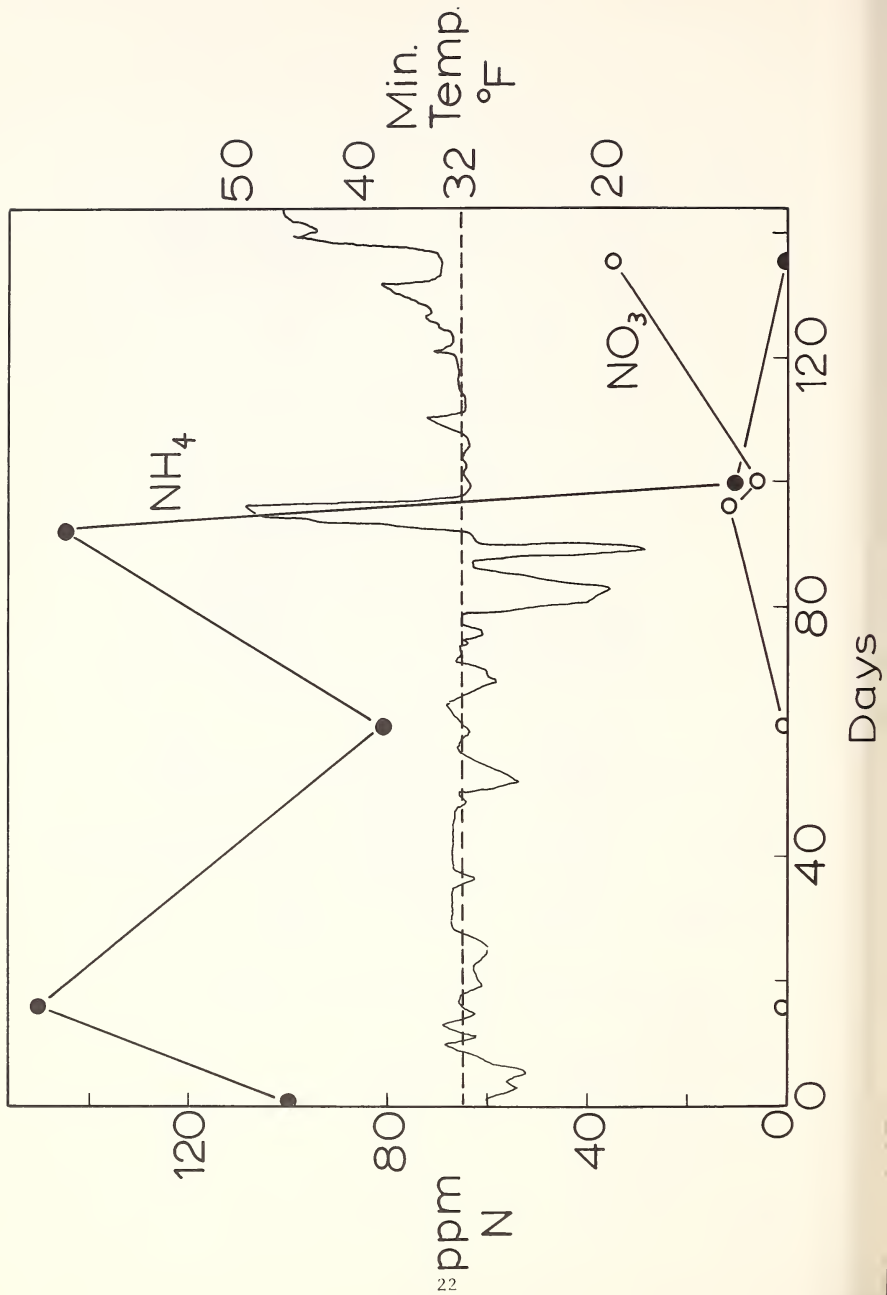
<u>% Corn Stalks</u>	<u>$\text{NO}_3\text{-N}$ loss in 6 Days</u> (ppm)
0	0
0.1	32.8
0.5	73.7

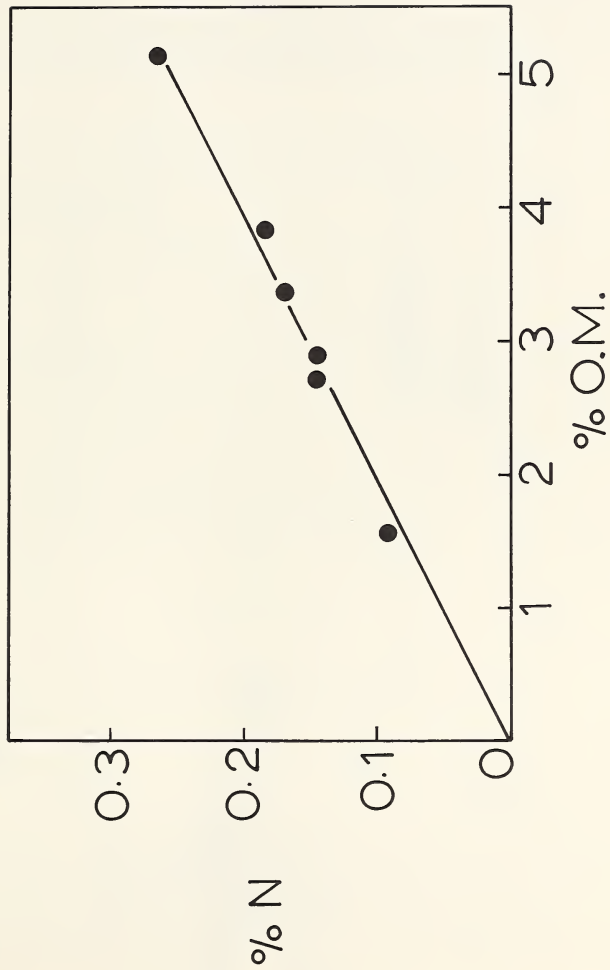
TABLE 8. Losses of N from Plowed Prairie

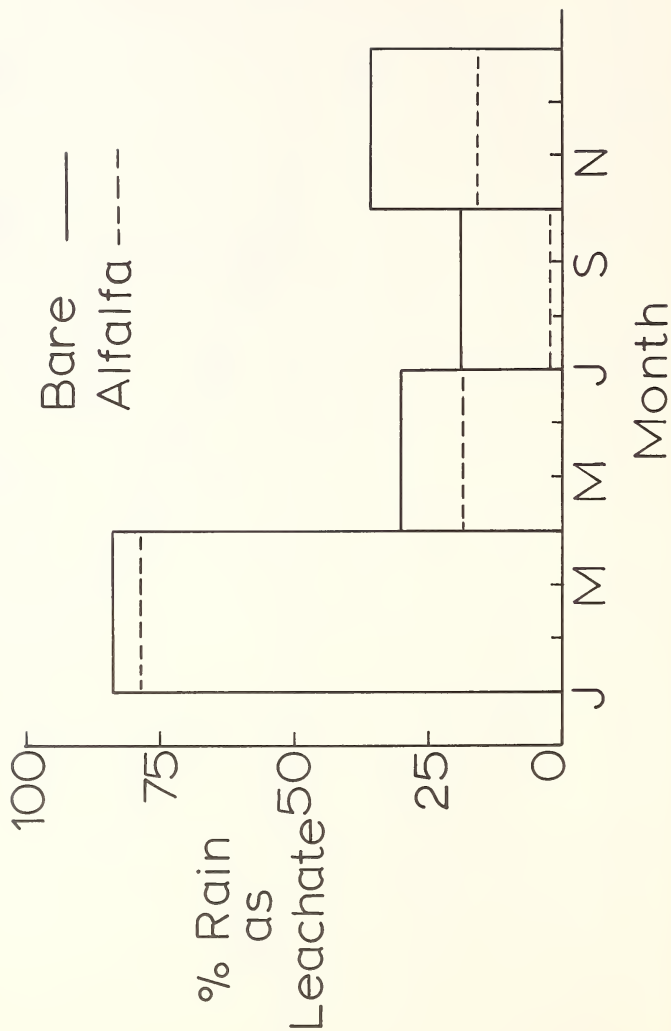
N in original	6940 lbs.
N after 22 years of plowing	4750 lbs.
Loss	2190 lbs.
Recovered in Crops	700 lbs.
Unaccounted for	1490 lbs.

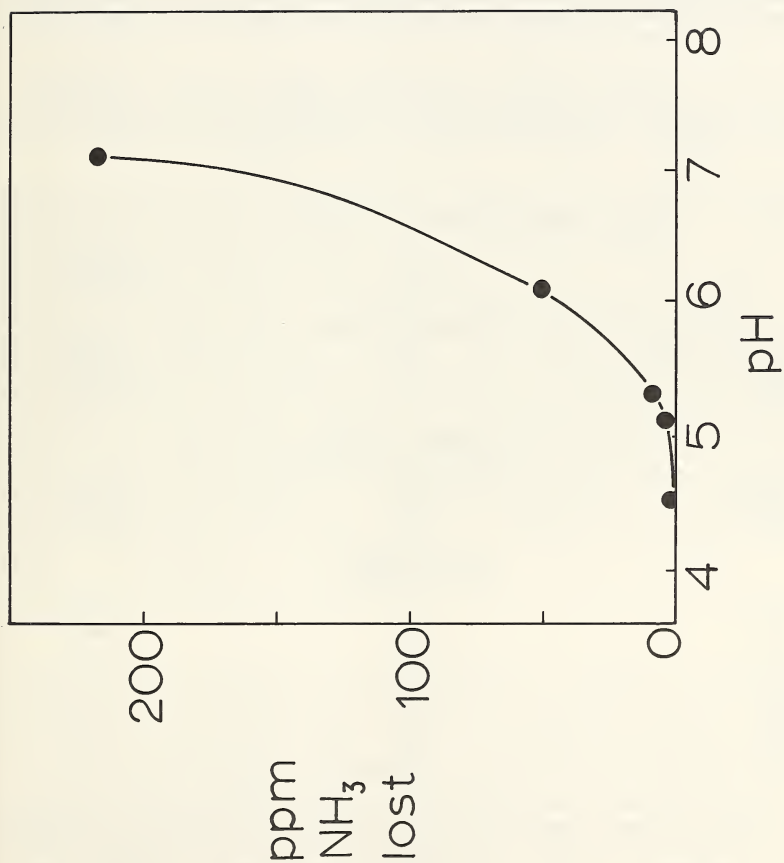
TABLE 9. Effect of Placement on N uptake by Grass

<u>Treatment</u>	<u>Harvest Dates</u>		<u>28 Sept.</u>	<u>% N Recovered</u>
	<u>14 July</u>	<u>12 Aug.</u> mg. N Taken up		
N surface	12.1	4.1	61.4	35
N 18 inches	32.0	11.2	59.2	59









Sources, Levels, Losses, and Availability of Mineral Elements in Soils

Warren B. Anderson
Texas A&M University

The main source of loss of most mineral elements in our soils occurred during previous weathering processes in the development of our present soils. Although current short-time weathering processes such as leaching do account for some current loss of mineral nutrients, greater quantities probably become unavailable to plants because of reaction and precipitation with other soil elements into unavailable forms.

Those mineral elements classified as nutrients essential both to plants and animals are categorized according to major, secondary, and micro-quantities required by plants. This categorization of relative plant requirement as well as some average soil nutrient levels are given in Table 1.

Table 1. Relative Levels of Minerals in Soils

Held As:	Element	Average (lb/A)
<u>Major Nutrients</u>		
Cation or Anion	N	2,000
Cation	K	20,000
Anion	P	2,000
<u>Secondary Nutrients</u>		
Cation	Ca	12,000
Cation	Mg	12,000
Anion	S	1,000
<u>Micronutrients</u>		
Cation	Fe	2,000
Cation	Mn	1,000
Cation	Zn	50
Cation	Cu	10
Anion	B	100
Anion	Cl	40
Anion	Mo	4

Not all of the nutrient elements which animal scientists consider essential to animals are required for plants. Since the elements Na, Co, I, and Se are not generally considered essential to the growth of most plants, supplying them directly in animal feed is considered more expedient than through the plant-food cycle.

The soil reaction or soil pH is an inherent soil factor which has a very decisive influence on the availability of mineral elements to plants. The range of soil pH in which the minerals are most readily available is given in Table 2.

Table 2. Soil pH in which minerals are most available to plants

Acid Soil	Neutral Soil	Alkaline Soil
Zn, Fe, Mn	N, P, K	Mo
Cu, B	Ca, Mg, S	

Soil test methods have been developed which determine the critical levels of the major nutrients quite satisfactorily; however, soil tests for most of the micronutrient elements are still in the developmental stages.

Nitrogen -- plants absorb as NH_4^+ or NO_3^- ions.

Nitrogen deficiency is apt to occur more frequently and more widespread than any other soil mineral nutrient because of the high requirement by most plants. Soil organic matter generally consists of about 5 percent N. Since most soils are rather low in organic matter, they are consequently even lower in the amount of N furnished. Commonly used N fertilizers generally supply the NH_4^+ form of N which is less subject to loss by leaching than is the NO_3^- form. However, under normal growing conditions, most of the NH_4^+ is soon nitrified to the NO_3^- form by soil bacteria and becomes very susceptible to leaching. Although there is a possibility of some fixation of NH_4^+ by clays making it unavailable to plants, the main problem of N availability is retaining it in the root growing area of the soil profile. To build up very much reserve supply of N in the soil is not feasible.

Potassium -- plants absorb as K^+ ion.

Potassium may be supplied by various inherent soil minerals such as: micas, biotite, muscovite, illite, and potash feldspars. Potassium is released by decomposition and disintegration of these soil minerals. However, if the rate of release is not adequate, then it must be supplemented by K fertilizers such as KCl , K_2SO_4 , KNO_3 , or $\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4$. Although K is somewhat subject both to leaching and fixation by shrinking-type clays, neither of these are generally serious problems. Thus, some build-up of K reserve in the soil can usually be recommended. A word of caution: If Mg is near a deficient level, heavy K application may induce a Mg deficiency.

Phosphorus -- plants absorb as H_2PO_4^- or $\text{HPO}_4^{=}$ ions.

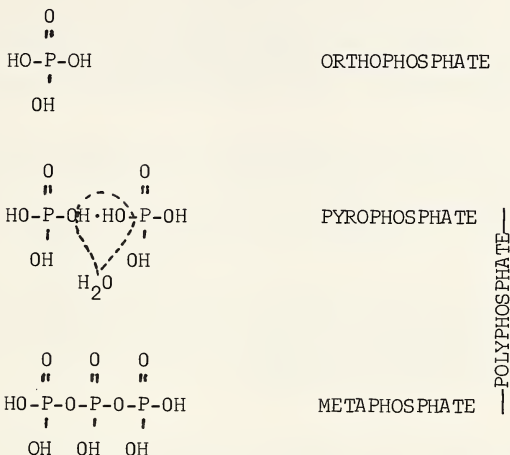
Phosphorus exists in only about 1/10 of the abundance of potassium in soils. Many soil minerals are sources of phosphorus which occur as inorganic combinations of PO_4 with Ca, Fe, Al, F, and other elements. The P in organic matter also contributes substantially. However, in acid soils most of the P has been weathered out, and in alkaline soils most of the P is tied up in unavailable forms. Consequently, most soils need P fertilizer applications. Since there is little hazard of losing P by leaching because of its inability to move through soils, a build up of reserve P supply is highly recommended. Common P fertilizer sources are: superphosphate, concentrated superphosphate, rock phosphate, phosphoric acid and ammonium phosphate. Caution must be observed since too high a build up has induced an imbalance of Zn and Fe.

The relative solubility or availability as well as the particular form of P obtained from various P fertilizers is shown in Table 3.

Table 3. Form of phosphorus supplied by common phosphorus fertilizers

	<u>Phosphorus Form</u>	<u>Fertilizer Material</u>
solubility decreases ↓	H_3PO_4 (Orthophosphate)	Phosphoric acid
	$\text{NH}_4(\text{H}_2\text{PO}_4)$ (Mono- or di-ammonium phosphate)	Ammonium phosphates
	$\text{Ca}(\text{H}_2\text{PO}_4)_2$ (Mono-calcium phosphate)	Super and concentrated superphosphates
	$\text{Ca}(\text{HPO}_4)$ (Di-calcium phosphate)	Ammoniated superphosphates
	$\text{Ca}_3(\text{PO}_4)_2$ (Tri-calcium phosphate)	Rock phosphates

A brief description of the new polyphosphate fertilizer materials follows:



When two or more orthophosphate molecules contained in phosphoric acid are condensed or polymerized together by heating to remove water molecules, the resulting product is polyphosphate material. These newly developed materials have received much publicity in recent years. However, research has shown that polyphosphates hydrolyze rapidly in the soil and thus revert back to the original orthophosphate form. Hence, there is not much advantage in the soil over other phosphate fertilizer sources. The main advantage of polyphosphates appears to be in transportation phase, both in hauling higher analyses and enhanced suspension of impurities, preventing settling out of gunk in liquid fertilizers.

Calcium and Magnesium -- plants absorb as Ca^{++} and Mg^{++} ions.

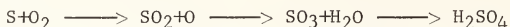
These two minerals are generally rather abundant in alkaline soils, but they are usually badly depleted from acid soils. Agricultural limestone is the most commonly used source of Ca and Mg. Calcitic limestone supplies only Ca, whereas dolomitic limestone supplies both Ca and Mg. Although they are both held by the cation exchange sites on the soil, they are subject to loss by extreme leaching conditions.

Heavy liming tends to reduce the availability of the micronutrients. Also, Mg deficiency can be induced or accentuated by high K fertilization when the Mg is near a critical level in the soil.

Sulfur -- absorbed by roots as SO_4^{--} , by leaves as SO_2

Since sulfur is generally contained in the soil in the anion form, and most soils don't have very much anion exchange capacity, there is not much reserve holding capacity. Most of the reserve pool of sulfur in soils is in the organic fraction. Consequently, S deficiency is most likely to occur in low organic matter soils. Other factors contributing to S deficiency are sandy soils, high rainfall leaching, use of high analysis pure fertilizers, and intense crop removal.

Common sources of sulfur are elemental S, gypsum, ammonium sulfate, or other sulfur-bearing fertilizers. The oxidation of elemental S increases the soil acidity as follows:



This reaction will increase the lime requirement of a soil. On the contrary, SO_4^{--} added to a soil does not acidify it. Many people have the mistaken idea that the SO_4^{--} from $(\text{NH}_4)_2\text{SO}_4$ fertilizer acidifies the soil. However, it is the oxidation and nitrification of the NH_4^+ ion which makes the soil acid, not the SO_4^{--} ion which is already fully oxidized.

Micronutrients

These so-called trace elements exist only in micro-quantities in most soils. They tend to be less available under neutral to alkaline soil conditions. Therefore, they occur deficient most often in alkaline or heavily limed acid soils.

The most readily obtainable sources of the micronutrient minerals are:

Zn, Fe, Mn, Cu

Sulfate salts
Chelate forms
Polyflavonoids
Oxides
Frits

B = borax or borates
Mo = sodium-molybdate sal
Cl = fertilizer salts and
irrigation waters

The reaction of applied micronutrients with other soil minerals to form less available reaction products is a prevalent problem, especially in alkaline soils. The accumulation and development of toxic levels from soil applications is probably a more intense problem than the concern for leaching and loss of those minerals from the soil.

The proper balance of mineral nutrients in the soil becomes very intricate. For example, there is considerable research evidence of heavy phosphorus fertilization causing an imbalance and inducing Zn and Fe deficiencies. The indiscriminate use of fertilizer minerals can cause more severe problems than it alleviates.

Utilization of Nitrogen and Minerals by Forage Plants

E. M. Evans
Auburn University

The theme of this symposium dictates a generalized agronomic approach to the topic. While admitting that science advances by postulating simple concepts, then discovering their limitations, I would like to interject a note of caution. Just because simple questions can be asked does not mean that there are simple answers.

The concept of soil fertility as a "bank account" in which deposits and withdrawals are made and a current "balance" obtained falls in the category of being "too simply conceived and attempts to explain too much." To illustrate, plant nutrient content is a function of a large number of factors several of which are usually unknown or uncontrolled in any given experiment. I shall enumerate a few of these factors.

1. The forage plant species, variety, or genetic strain has a great influence on its ability to accumulate and utilize nutrient ions.
2. The age or physiologic growth stage of the plant enormously affects its nutrient content.
3. The nature of the soil and its content of "available" nutrients are of great importance to the nutrition of the plant.
4. Weather conditions, both current and preceding, determine in a large measure the plant response to fertilizer treatment.
5. Insect and disease predators can nullify applied treatments and modify expected results.
6. The species combination (grass + legume + weeds), or total plant community, is more than the sum of its parts studied separately. This may lead to surprising results.
7. Plants, though generally thought to be passive victims of their soil environment, do exert an influence on the soil's chemistry, physics, and microbiology. These effects may result in greater "availability" of nutrients than anticipated.

These preliminary cautions are not intended to deny the value of the concepts advanced. It is hoped, instead, to stimulate a synthesis, by a group of brilliant young plant scientists, of these postulates into a more generalized and perhaps fundamental approach to forage plant nutrition. Such is badly needed to help explain the complex interactions included in multi-species forage combinations.

A concept that has proved useful is that of the "critical percentage" of a given nutrient element in the plant. This is exemplified in a 3-year study by Gerwig and Ahlgren (1) on alfalfa. Actually, they found two "critical

percentages" for potassium. The content needed for maximum yield was between 1.42 and 1.84 percent and varied from season to season. The "critical percentage" for stand survival under "normal management practices" was said to be near 1.0 percent. Actual contents of K ranged from 0.99 to 2.79 percent over an application range of 0 to 400 lbs K_2O . Yields ranged from 2 to 5 tons per acre over all during the 3-year period.

Critical percent for phosphorus in alfalfa has been set at 0.27. The New Jersey study indicated it to be less than 0.25 percent, which was the lowest obtained, and there was no growth response to phosphorus. The range in P content was 0.25 to 0.35 percent.

Calcium levels ranged from 1.20 to 1.96 percent with the highest being on the unfertilized check plot. An increase in K resulted in a decreased content of Ca.

Magnesium ranged from 0.15 to 0.43 percent and decreased, as did Ca, with each increment of K. This is in accord with the "cation equivalency" constant as suggested by numerous workers.

Kilmer, et al. (2) in Maryland studied yield and mineral content of a wide range of cool season legumes and grasses as affected by levels of soil moisture. Alfalfa, white and red clover, tall fescue, orchardgrass, and Reed canarygrass were included. Composition was determined for the third harvest. Typical values are N, 3.5 percent; P, 0.25; K, 2.5; Ca, 1.4; Mg, 0.45; and S, 0.17 for the legumes. Grasses were slightly lower in nitrogen content (2.85 percent) and considerably lower in calcium (0.37) but otherwise quite similar to the legumes. One notable exception was the sulfur content of Reed canarygrass (0.30 percent). There was no direct effect of cation concentration due to differences in soil moisture. The concentration of phosphorus in the forages increased (by 0.06 to 0.08 percent) as soil moisture supply was increased. Total uptake of all major elements was generally enhanced by increasing the moisture supply.

Ramage, et al. (3) studied yield and content of orchardgrass and Reed canarygrass under heavy nitrogen fertilization in New Jersey. Yields averaged from 2 to 4½ tons per acre over a 3-year period when fertilized with 50 to 400 lb N per acre annually. Protein content ranged from 12 to 20 percent. Recovery of N was about 60 percent over all, with the 100 lb N rate at 73 percent. Eighty-three pounds of K per acre were applied; removals over the 3-year period ranged from 377 lb at the 40 lb N rate to 635 lb at the 400 N rate on orchardgrass. Average K contents of the forage ranged from 1.6 to 2.9 percent for orchardgrass and from 1.7 to 2.5 percent for Reed canarygrass. First cut of first year grass had a K content greater than 3.0 percent.

In a 5-year study of sources of phosphorus for several cool-season legumes, Jackson and Burton (4) reported phosphorus contents ranging from 0.15 to 0.24 percent on a Virgin Rains soil. P removals ranged from 20 to 50 lb/A annually, with a yield range from 1 to 2½ tons/A. Application rates varied from 15 lb/A from concentrated superphosphate to 1,200 lb from the raw rock phosphate source.

In another study of sources of phosphorus with rates of lime on a heavy acid clay, Ensminger and Evans (5) found P contents of white clover to range from 0.15 percent from raw rock phosphate at the 3 tons/A lime rate to 0.31 percent for superphosphate under the same conditions. Comparable yields were 793 lb/A for the former treatment and 6,243 lb for the latter. Yield and P content both declined for the rock phosphate source with addition of lime.

From the foregoing it can be surmised that cool season grasses and legumes, when reasonably well fertilized and with reasonable management, have the capacity to take up nutrient elements to such an extent that the forage content is usually in the adequate to luxury range for most classes of livestock. This is generally true, and these forages are generally recognized as being of adequate to high quality. Yields are generally in the modest range and fertilizer applications at least systematic. Under grazing conditions the situation would usually be even more conservative or less demanding.

With warm-season perennial grasses there is a different situation. A few citations will serve to illustrate this point.

Fisher and Caldwell (6) produced 13.2 tons of dry Coastal bermudagrass annually in Texas with irrigation and application of 1180 lb of N per acre. It contained about 13 percent crude protein, 0.53 percent P_2O_5 , 2.2 percent K_2O , 0.19 percent Mg, and 0.35 percent Ca, according to their report. Conversion gives 0.23 percent P and 1.83 percent K.

Jackson, et al. (7) in Georgia found contents of Coastal bermudagrass to be 0.4 to 2.0 percent K with applications of 0 to 200 lb K_2O per acre and yields ranging from 5 to 7 tons annually at the 200 lb N rate. A content of 0.8 to 1.0 was considered adequate for maximum yield. Annual application of 100 lb K_2O per acre failed to maintain the soil K level above the "low" value in the surface 6-inch soil zone.

Evans, et al. (8) reported contents of Coastal bermudagrass on a sandy loam soil in central Alabama to range from 1.23 to 2.45 percent N over a treatment range of 0 to 600 lb N. P was about 0.26 percent and K about 1.7. Total uptake at the 600 lb N rate was equivalent to 457 lb N, 115 lb P_2O_5 , and 330 lb K_2O per acre. Pensacola bahiagrass in the same experiment had quite similar contents.

No claim is made for completeness in presenting this subject. When we consider that calcium, magnesium, and sulfur have been applied incidentally to correcting soil reaction and supplying phosphorus, and that the greatest effort on behalf of micronutrients has been exerted to discover if we have soils on which response can be obtained, then it is not too surprising that most of the energy has been devoted to the elements N, P, and K.

Literature Cited

1. Gerwig, J. L. and G. H. Ahlgren. 1958. The effect of different fertility levels on yield, persistence, and chemical composition of alfalfa. Agron. J. 50:291-294.
2. Kilmer, V. J., Orus L. Bennett, Virginia F. Stahly, and Donald R. Timmons. 1960. Yield and mineral composition of eight forage species grown at four levels of soil moisture. Agron. J. 52:282-285.
3. Ramage, C. H., Claude Eby, Robert E. Mather, and Ernest R. Purvis. 1958. Yield and chemical composition of grasses fertilized heavily with nitrogen. Agron. J. 50:59-62.
4. Jackson, J. E. and G. W. Burton. 1960. A five-year comparison of rock phosphate and concentrated superphosphate for several forage crops. Agron. J. 52:692-694.
5. Ensminger, L. E. and E. M. Evans. 1960. Establishment and maintenance of white clover-grass pastures. Auburn Univ. Agr. Exp. Sta. Bull. 327.
6. Fisher, F. L. and A. G. Caldwell. 1959. The effects of continued use of heavy rates of fertilizers on forage production and quality of Coastal bermudagrass. Agron. J. 51:99-102.
7. Jackson, J. E., M. E. Walker, and R. I. Carter. 1959. Nitrogen, phosphorus, and potassium requirements of Coastal bermudagrass on a Tifton loamy sand. Agron. J. 51:129-131.
8. Evans, E. M., L. E. Ensminger, B. D. Doss, and O. L. Bennett. 1961. Nitrogen and moisture requirements of Coastal bermuda and Pensacola bahia. Auburn Univ. Agr. Exp. Sta. Bull. 337.

The Fate of Nutrients in the Excreta of Grazing Animals

W. W. Woodhouse, Jr.
North Carolina State University, Raleigh

It has been reasoned by some that since (1) a high proportion of the N, P, and K consumed by the grazing animal (75 to 90 percent for mature cattle) passes through, and (2) it is, therefore, subject to recycling, one needs to inject only relatively small amounts of these nutrients into the system from time to time in order to attain and perpetuate an ample nutrient level over a pasture.

Actually, the soil-plant-animal complex has received very little study directed specifically at this question. Most of the studies along this line have centered on the effect of excretal return on pasture production as measured with animals. Results have been conflicting--quite positive in some cases (Mott, 1970), negative in others (Sears, 1950)--for reasons that are not well understood.

My remarks will be confined largely to another approach--attempts, through agronomic methods, to get at the fate of individual nutrients (Petersen, 1956; Lotero, 1965).

Petersen studied the distribution of excreta and the probable distribution of nutrients by grazing cattle. He concluded that cattle are not very efficient distributors of nutrients, applying high rates on small areas, and he points out that the effect of the nutrients returned is very much dependent upon (1) excretal density; i.e., stocking rate, and (2) loss rate of the individual nutrient. His findings suggest that the effectiveness of excretal return could vary widely between nutrients and between regions, being affected greatly by differences in soils, climate, and classes of animals.

Lotero looked at size and shape of urine spots applied by cattle, and he attempted to determine for N and K such things as effective area, loss rate, and factors affecting these. It would appear from his studies that at the usual stocking rates with cattle, under the dominant soil and climatic conditions of the Southeastern U.S., recycling of N and K could not be expected to maintain a pasture at a really high level of productivity. It might, at any given time, for example, triple or quadruple the yield of 10 to 15 percent of the area, leaving 85 to 90 percent unaffected. P, having a much lower loss rate, could eventually affect a high proportion of a pasture. Changes in stocking rates, classes of livestock, and differences in soils and climate would alter this expectation. The proportion of the area affected by recycling N or K could become quite high under a favorable combination of these factors. This evidently does happen, but it has not been recognized in the Southeastern U.S. There is a real need for information on this phenomenon in this region. The economic implications are substantial.

Literature Cited

- Lotero, J., W. W. Woodhouse, Jr., and R. G. Petersen. 1965. IX intern. Grassland Cong., p. 1687.
- Mott, G. O., L. R. Quinn, and W. V. A. Bisschoff. 1970. XI Intern. Grassland Congr.
- Petersen, R. G., H. L. Lucas, and W. W. Woodhouse, Jr. 1956. Agron. J. 48:440.
- Sears, P. D. 1950. J. Brit. Grassland Soc. 5:267.

Pre-Conference Executive Committee Meeting, Tuesday, July 14, 1970

The Executive Committee meeting of SPFCIC was called to order at 5:15 p.m. by Chairman C. L. Mondart, Jr. Present were McCroskey, Lusk, and Montgomery (Past Chairman, Chairman, and Secretary, S-45); Buckner, Powell, Taliaferro, and R. Smith (Program Chairman, Chairman, Secretary, and Secretary-Elect, SFBG); Woodhouse (Vice-Chairman, SFPEWG); Dobson and J. Burns (Past Chairman and Chairman, SFEWG); and Taylor, Riewe, Timothy, Valez-Fortuno, and Leffel (Past-past Chairman, Past, and Program Chairman, Chairman Elect, Chairman Elect-elect, and Secretary, SPECIC). A question was raised as to whom constitutes the Executive Committee; Leffel cited from the minutes: "The Chairmen (or their designated representative) and Past Chairmen of Interest Groups (1 vote per group) and officers of SPFCIC, all constituting the Executive Committee of SPFCIC...". It was pointed out that S-45 changes officers with calendar years; the Work Groups elect officers at Annual Meetings. Leffel is to study and report on composition of Executive Committee.

Chairman Mondart announced that the Nomination Committee is H. D. Ellzey, J. D. Burns, and John Moore, Chairman; and that the Resolutions Committee is T. H. Taylor, J. H. Reynolds, and C. Y. Ward, Chairman. Chairman Mondart read a letter of invitation for 1971 SPFCIC meeting from Oklahoma and explained a change in date of meeting at Clemson (from 1971 to 1972). The Executive Committee will recommend acceptance of these invitations by the Conference.

Taliaferro reported that the Oklahoma State University Conference Coordinator finds most suitable dates for 1971 meeting June 15 to July 15, or later in July, and requests notice of any conflict with other meetings. It was pointed out that when we use University Conference Centers, registration fees are set by the Center. Leffel reported a Treasurer's balance of \$157.21.

Chairman Mondart announced that the Forage Evaluation Committee will give a report at the general business meeting. Also, receipts for registration fees will be available at Registration Desk.

Valez-Fortuno reported that he expects to obtain sabbatic leave August 1971 to August 1972, and requested whatever adjustment needed within SPFCIC Officers' duties. Chairman Mondart announced the next meeting tomorrow night immediately after the Banquet. The meeting was adjourned at 5:50 P.M.

Report of Forage Evaluation Committee - SPFCIC

The S-45 Regional Project Technical Committee, acting as the Forage Evaluation Committee of SPFCIC, presents the following report:

1. The two-stage in vitro dry matter digestion (Tilley and Terry) technique is still recommended as the best universal technique available for evaluating the quality of small samples. An adaptation of the Tilley and Terry procedure was outlined in detail by R. F. Barnes in the Proceedings of the National Conference on Forage Evaluation and Utilization, Lincoln, Nebraska, September 1969. Barnes presented data from a collaborative study and reported that good agreement between laboratories was found when all the collaborating laboratories used the same technique.

2. The Dairy and Pasture Experiment Station, Franklinton, Louisiana, found that the in vitro cell wall digestibility technique of Van Soest was somewhat superior to the in vitro dry matter digestibility technique for their forages.

3. Kentucky found that solubility of forage dry matter in HCl-Pepsin was a good predictor of the quality of cool season forage but not warm season forage. Cool season forages generally have a higher percentage of soluble constituents than do the warm season forages, which may explain the Kentucky results. The HCl-Pepsin procedure was discussed by E. Donefer in the proceedings of the Nebraska conference mentioned above.

4. Mississippi has found that, for grain sorghum silages, the cell wall content is the best predictor of nutritive value.

5. The Texas Extension Service forage testing program began on July 1, 1970, to use forage cell wall constituents instead of crude fiber in their program. They use a formula based on crude protein and cell wall constituents to estimate TDN and net energy. The program has continued to use chemical rather than in vitro techniques because the rather small numbers of hay and silage samples analyzed did not justify the expense of maintaining a fistulated animal as a donor of rumen fluid for the in vitro technique. The cell wall technique has been published by Van Soest and will appear in a new USDA Bulletin "Forage Fiber Analyses" soon to be published.

6. As a point of information, the revision of the S-45 project has been officially approved. The title of the new project is "Relationship Between Properties of Southern Forages and Animal Response." The project will involve harvesting forages as hays and feeding them to growing cattle to determine voluntary intake and rate and efficiency of gain. Nutrient digestibility will also be determined and, in some cases, energy utilization and nutrient absorption will also be measured. Each forage fed to animals will be completely characterized in the laboratory. New approaches to forage characterization will also be evaluated. The laboratory data will be compared to the animal response data by statistical procedures designed to develop equations for predicting forage quality from laboratory tests. The forages to be included initially are alfalfa, bahiagrass, bermudagrass, tall fescue, orchardgrass,

pangolagrass, and a sorghum-sudangrass hybrid. Each will be studied at three stages of maturity by at least two stations. The committee hopes that this project will help to identify the factors limiting the quality of southern forages and will provide new and improved laboratory procedures which can confidently be recommended as techniques for evaluating the quality of small forage samples.

Respectfully submitted for the S-45 committee, by J. E. Moore.

Report of Resolutions Committee

It is a distinct pleasure to present to you this report of the Resolutions Committee.

Whereas--This 27th Annual Conference of the SPFGIC has proved to be of inestimable benefit to all attendees, and whereas these benefits were the results of the concerted efforts of the program committee and the capable participants; be it Resolved: That this 27th Conference expresses the sincere appreciation of its membership to the administration and Staff of the University of Georgia for the hospitality extended and the excellent facilities provided during the meeting in Athens and the field trips to cooperative research in Allied Laboratories and at Watkinsville.

We are indebted to the outstanding "Local Arrangements Committee" of D. G. Cummins, J. B. Powell, E. R. Beaty, W. H. Sell, S. R. Wilkinson, and R. H. Brown, Chairman. Special thanks are due the conference chairman, C. L. Mondart, Jr., and to our esteemed permanent secretary, R. C. Leffel, for their effective leadership during the past year, and to M. E. Riewe who has served as 1970 program chairman.

We move that this resolution be adopted and recorded in the minutes and, further, that a copy of this resolution and letters of appreciation be sent to Dr. L. W. Eberhardt, Director, Extension; Dr. W. P. Flatt, Director of the Georgia Agricultural Experiment Station; and Dr. Henry Garren, Dean of the College of Agriculture, University of Georgia.

John H. Reynolds
Timothy H. Taylor
Coleman Y. Ward

SPFCIC General Business Meeting, Wednesday, July 15, 1970

The general business meeting of SPFCIC was called to order at 4:45 P.M. by Chairman C. L. Mondart, Jr. Harold Brown explained Tours planned for Thursday. The Forage Evaluation Committee Report was given by John Moore, copy enclosed. It was announced that S-45 is continued for the next 5 years.

Report of Nominating Committee by John Moore nominated Robert Buckner of University of Kentucky and ARS as Chairman Elect-Elect of SPFCIC; the motion to close the nominations and to elect Dr. Buckner by acclamation carried unanimously.

Chairman Mondart read a letter from Dean and Director J. A. Whatley inviting SPFCIC and associated Work Groups to Oklahoma in 1971. The motion to accept the invitation carried unanimously. The Host will designate time of meeting as soon as possible.

The Report of the Resolutions Committee is to be given at Banquet tonight; a copy is enclosed. Chairman Mondart expressed thanks to the Program Chairman and to Program participants and requested that a copy of each paper be forwarded to the Secretary as soon as possible. The executive Committee meeting was announced for Room 2B, immediately after the Banquet. The meeting was adjourned at 5:00 P.M.

SPFCIC Executive Committee Meeting, Wednesday, July 15, 1970

The Executive Committee meeting was called to order at 9:50 P.M. by Chairman Mondart. Present were McCroskey, Lusk, and Montgomery (S-45); Taliaferro (SFBC); Woodhouse (SFPEWG); J. Burns and White (SFEWG); and Riewe, Timothy, Velez-Fortuno, Buckner, and Leffel (SPFCIC). Current officers of Work Groups and Conference are as follows:

	<u>S-45</u>	<u>SFBC</u>	<u>SFPEWG</u>
Adm. Adv.	C. O. Little	O. B. Garrison	A. T. Wallace
P-P Chr.			
P Chr.	<u>J. E. McCroskey</u>	<u>J. P. Powell</u>	<u>C. S. Hoveland</u>
Chairman	<u>J. W. Lusk</u>	<u>C. M. Taliaferro</u>	<u>W. W. Woodhouse, Jr.</u>
Chr. E.	M. J. Montgomery		G. L. Spain
Chr. E-E			
Secretary		R. L. Smith	R. H. Brown

SFEWGSPFCIC

Adm. Adv.
P-P Chr.
P Chr.
Chairman
Chr. E.
Chr. E-E
Secretary

P. H. DeHart
J. D. Burns
H. E. White

J. R. Johnson

M. E. Riewe
C. L. Mondart, Jr.
D. H. Timothy
J. Velez-Fortuno
R. C. Buckner
R. C. Leffel

Members of SPFCIC Executive Committee are underlined. Chairmen (or their designated representative) and Past Chairmen of Interest Groups (1 vote per Interest Group) and officers of SPFCIC shall constitute the Executive Committee of SPFCIC.

Taliaferro indicated that 1971 meeting at Oklahoma will probably be first or second week of July. Chairman Mondart called for suggestions and discussion of 1971 Program:

Timothy suggested consideration of range grasses at Oklahoma meeting. Taliaferro suggested forage systems, or forages in a system--i.e., how to fit various forages into a total forage program. It was generally agreed that treatment of principles of systems could provide a one-half day program, and that it would utilize soils, plant, and animal specialists. Efficiency of production of animal products was suggested as a topic, with emphasis on production of lean and hamburger beef. Riewe questioned as to whether the need was one of research to tell us how to do it--or one of motivation to do, with known principles. How do we get farmers to accept practices the scientists know will give high and, presumably, efficient production? Utilization of forages by grazing versus confinement feeding was suggested as a topic. It was suggested that one species be treated intensively; e.g., fescue, bermudagrass, or sorghum-sudangrasses. Advances in forage crops--or breakthrough--or even speculation on same, was suggested. A question was raised relative to new grasses on the horizon--or new species for specialized purposes. Biochemistry of adaptation--e.g., the role of enzyme system(s) in tropical versus temperate species, or in summer versus winter species, was suggested. Systems of forage handling; i.e., grazing, greenchop, etc., was mentioned. Animal utilization problems with summer annuals, such as prussic acid or nitrate poisoning, was suggested. Role of summer annuals in a beef or dairy operation, or the role of annuals in a 12-month program, were additional suggestions. It was agreed that the 1971 topic will be Summer Annuals. Program suggestions and recommendations for program speakers should be sent to Dr. Mondart. Oklahoma will present a 2-hour program on the State's forage research program.

The meeting was adjourned at 10:55 P.M.

SOUTHERN FORAGE BREEDERS' GROUP
July 14, 1970

J. B. Powell, Presiding

Cytoplasmic Male Sterility

John R. Edwardson
University of Florida

Gene-cytoplasm interactions inducing male sterility have been reported for 153 species in 51 genera in 22 families of plants. Most of these reports involve studies of inheritance or of the application of cytoplasmic male sterility to producing commercial hybrids. Locating sterility factors, determining how they are transmitted, and elucidating mechanisms controlling sterility have received less attention than the use of cytoplasmic sterility to exploit heterosis.

Although ionizing radiation (22, 23, 24), colchicine (9), and interspecific crossing (5) have been assumed to induce cytoplasmic male sterility, the nature of the affected cytoplasmic factors and their location are unknown.

Exceptions circumscribe most generalizations concerning the attributes of cytoplasmic sterility. That cytoplasmic sterility factors are not transmitted by pollen but are transmitted through seed are generalizations which currently stand without exceptions. Mechanisms governing sterility are by-passed or temporarily suppressed by action of fertility restorer genes. However, Bond et al. (3) report irreversible suppression of the system controlling sterility by restorer genes in Vicia faba.

In most cases sterility is sporophytic; however, gametophytic sterility has been reported in *Aegilops* (21), rice (36), and in corn containing S-type cytoplasm (4).

Mechanisms which induce pollen abortion have been proposed to control the following: 1. High callase activity which inhibits meiosis in *Petunia* (12); 2. abnormal cytochrome oxidase systems resulting in insufficient oxidative phosphorylations in sudangrass (1); 3. inability of microspores to absorb nutrients in onion (40); 4. impaired functioning of conductive tissue in filaments leading to nutritional imbalance in microspores of beet (32); and 5. nucleolar abnormalities which suppress pollen mitosis in corn (17). Assumptions underlying these proposed mechanisms have not yet been rigorously tested.

Attempts to understand uniparental transmission of male sterility are at present based on assumptions that sterility factors are: 1. located in cytoplasmic organelles; 2. located in infective agents; 3. products of a regulator-operon system in which cytoplasmic factors play no role. That sterility factors in *Oenothera* are located in plastids is indicated in the studies of Schwemmler, et al. (33), Stinson (37), Stubbe (38), and others, while the

investigations of Michaelis (27) also implicate plastids as sites of sterility factors in *Epilobium*. Lombardo and Gerola (25) report generative cells of angiosperm pollen contain many mitochondria, but proplastids were tentatively identified in generative cells of only a few species. These investigations suggest that plastids rather than mitochondria may be the sites of cytoplasmic sterility factors in many species; however, this must remain a conjecture in the absence of information concerning the fate of paternal mitochondria in pre- and post-zygotic developmental stages. Rhodes' (31) suggestion that the cytoplasmic factors of S-type sterile corn are located in mitochondria has not been tested.

According to Michaelis (26), Kohler in 1928 was probably the first to suggest that some cases of cytoplasmically inherited pollen sterility might be explained by assuming virus transmission. There is some evidence that cytoplasmic sterility factors are infectious in *Petunia* (2, 8, 10, 11), and sugar beet (6). However, if infections are involved in these studies they do not resemble, in several respects, infections induced by any known virus. Regularity of transmission through seed, absence of symptom expression in the graft generation, absence of meiotic disturbances, and unimpaired female fertility are not properties usually associated with viruses.

Although opinions regarding sites of cytoplasmic sterility factors are diverse, there is general agreement about their composition. The assumption that sterility factors contain nucleic acids is based on extrapolations from the presence of nucleic acids in cytoplasmic organelles (15, 29, 39), in bacterial plasmids (30), and in infective agents (14, 35). However, the nucleic acid of sterility factors may not necessarily be associated with organelles or with proteins; the potato spindle tuber virus (7) and the exocortis virus of citrus (34) are believed to consist of free ribonucleic acid. It is not known whether infectious agents similar to the scrapie factor (13, 16) found in animals also exist in plants. There is evidence that the scrapie factor does not contain nucleic acid (20).

Heslop-Harrison (18, 19) has presented a modification of Monod and Jacob's (28) Model II induction system in *Escherichia coli* to account for male sterility in plants. Heslop-Harrison (18, 19) assumes that a regulator-operon system "A" in an induced state exists in "cytoplasmic" male-sterile plants, and he further assumes that the inducer, which is continually synthesized by this system, also acts as a repressor to a second system "B"; the "B" system controls stamen formation. The "B" system, which is permanently repressed in male-sterile plants, is assumed to exist in the induced state in normal plants, while the "A" system in normal plants would be repressed. These assumptions formally account for male sterility and fertility in gynodioecious systems; however, their application to systems containing fertility restorer genes, or to systems exhibiting asexual transmission of sterility, have not been attempted.

Investigations involving *Oenothera* and *Epilobium* support the assumption which would locate sterility factors in plastids. While cytoplasmic sterility factors may exist in other organelles in some cases, and in the form of infectious agents in others, these assumptions await supporting experimental evidence.

Literature Cited

1. Alam, S. and P. C. Sandal. 1967. Cyto-histological investigations of pollen abortion in male-sterile sudangrass. *Crop Sci.* 7:587-589.
2. Bianchi, F. 1963. Transmission of male sterility in *Petunia* by grafting. *Genen et Phaenen* 8:36-43.
3. Bond, D. A., J. L. Fyfe, and G. Toynbee-Clarke. 1966. Male sterility in field beans (*Vicia faba* L.) III. *J. Agr. Sci. Camb.* 66:359-367.
4. Buchert, J. G. 1961. The stage of the genome-plasmon interaction in the restoration of fertility to cytoplasmically pollen-sterile maize. *Proc. Natl. Acad. Sci.* 47:1436-1440.
5. Burk, L. G. 1960. Male-sterile flower anomalies in interspecific tobacco hybrids. *J. Hered.* 51:27-31.
6. Curtis, G. J. 1967. Graft-transmission of male sterility in sugar beet (*Beta vulgaris* L.). *Euphytica* 16:419-424.
7. Diener, T. O. and W. B. Raymer. 1967. Potato spindle tuber virus: a plant virus with properties of a free nucleic acid. *Science* 158:378-381.
8. Edwardson, J. R. and M. K. Corbett. 1961. Asexual transmission of cytoplasmic male sterility. *Proc. Nat. Acad. Sci.* 47:390-396.
9. Erickson, A. W. and J. G. Ross. 1963. Inheritance of colchicine induced male sterility in sorghum. *Crop Sci.* 3:335-338.
10. Frankel, R. 1956. Graft-induced transmission to progeny of cytoplasmic male sterility in *petunia*. *Science* 124:684-685.
11. Frankel, R. 1962. Further evidence on graft induced transmission to progeny of cytoplasmic male sterility in *Petunia*. *Genetics* 47:641-646.
12. Frankel, R., S. Izhar, and J. Nitsan. 1969. The timing of callase activity and cytoplasmic male sterility in *Petunia*. *Biochem. Genet.* 3:451-455.
13. Gibbons, R. A. and G. D. Hunter. 1967. Nature of the scrapie agent. *Nature* 215:1041-1043.
14. Gibbs, A. 1969. Plant virus classification. *Adv. in Virus Res.* 14: 263-328.
15. Gibor, A. 1965. Chloroplast heredity and nucleic acids. *Amer. Nat.* 99:229-240.
16. Griffith, J. S. 1967. Self-replication and scrapie. *Nature* 215:1043-1044.

17. Herich, R. 1965. Nucleoli and cytoplasmic male sterility. Zeits. Vererb. 96:22-27.
18. Heslop-Harrison, J. 1963. Sex expression in flowering plants. Brookhaven Symp. Biol. 16:109-125.
19. Heslop-Harrison, J. 1967. Differentiation. Ann. Rev. Plant Physiol. 18:325-348.
20. Hunter, G. D., R. H. Kimberlin, and R. A. Gibbons. 1968. Scrapie: A modified membran hypothesis. J. Theoret. Biol. 20:355-357.
21. Kihara, H. 1950. Japanese papers on genetics. 1942-1948. English Abstracts. Heredity 4:401.
22. Kinoshita, T. and S. Nagao. 1968. Use of male sterility in triploid sugar beets. Proc. XII Int. Cong. Genet. 232-233.
23. Kinoshita, T. and M. Takahashi. 1966. Inheritance of a pollen sterility induced by irradiation. Bull. Sugar Beet Res. Suppl. 7:40-42.
24. Lindstrom, E. E. 1953. Heredity radium-induced variations in the tomato. J. Hered. 24:129-137.
25. Lombardo, G. and F. M. Gerola. 1969. Cytoplasmic inheritance and ultra-structure of the male generative cell of higher plants. Planta 82: 105-110.
26. Michaelis, P. 1964. Virus und zytoplasmatische Vererbung. Zeits. Pflanzenzucht. 52:333-354.
27. Michaelis, P. 1969. Über Plastiden-Restitutionen (Rückmutationen). Cytologia 34:1-115.
28. Monod, J. and F. Jacob. 1961. General conclusions: Telenomic mechanisms in metabolism, growth and differentiation. Cold Spring Harbor Symp. Quant. Biol. 26:389-401.
29. Nass, M. N. K. 1969. Mitochondrial DNA: Advances, problems, and goals. Science 165:25-35.
30. Novick, R. P. 1969. Extrachromosomal inheritance in bacteria. Bact. Rev. 33:210-235.
31. Rhoades, M. M. 1950. Gene induced mutation of a heritable cytoplasmic factor producing male sterility in maize. Proc. Nat. Acad. Sci. 36:634-635.
32. Rohrbach, U. 1965. Beiträge zum Problem der Pollensterilität bei Beta vulgaris L. I. Untersuchungen über die Ontogenese des Phänotyps. Zeits. Pflanzenzucht. 53:105-124.

33. Schwemmle, J., E. Haustein, A. Sturm, and M. Binder. 1938. Genetische und Cytologische Untersuchungen an Eu-Oenotheren I-IV. Zeits. Ind. Abst. Vererb 75:358-800.
34. Semancik, J. S. and L. G. Weathers. 1968. Exocortis virus of citrus: Association of infectivity with nucleic acid preparations. Virology 36:326-328.
35. Shepherd, R. J., R. J. Wakeman, and R. R. Romanko. 1968. DNA in cauliflower mosaic virus. Virology 36:150-152.
36. Shinjyo, C. 1969. Cytoplasmic-genetic male sterility in cultivated rice, Oryza sativa. II. The inheritance of male sterility. Japan J. Genet. 44:149-156.
37. Stinson, H. T. 1960. Extranuclear barriers to interspecific hybridization between Oenothera hookeri and Oenothera argillicola. Genetics 45:819-839.
38. Stubbe, W. 1964. The role of the plastome in evolution of the genus Oenothera. Genetica 35:28-33.
39. Swift, H. 1965. Nucleic acids of mitochondria and chloroplasts. Amer. Nat. 99:201-228.
40. Virnich, H. 1967. Untersuchungen über das Verhalten der männlichen Sterilität und anderer Eigenschaften bei polyploiden Zwiebeln (Allium cepa L.) als Grundlage für eine Nutzung in der Hybridauchtung. Zeits. Pflanzenzucht. 58:205-244.

Application of Male Sterility to Forage Legume Breeding

R. R. Smith
USDA, ARS, CR, Madison, Wisconsin

Male sterility conditioned by nuclear factors has been reported in numerous legume species. Cytoplasmic male sterility has been reported in at least four legume genera--Crotalaria (14), Desmodium (21), Medicago (5, 9, 27), and Vicia (4). Evidence to establish cytoplasmic male sterility reject alternative hypotheses based on Mendelian principles. The best evidence is obtained by backcrossing F_1 and subsequent progenies to the original male-sterile source. Supporting evidence can be obtained from reciprocal crosses when such crosses are available. Both backcrossing and the results of reciprocal crosses were used in Desmodium (21) and Medicago (5, 27) to provide supporting evidence for cytoplasmic male sterility in these species.

Probably the most evident use of any form of male sterility is the production of hybrids. However, some less perceptible uses are those which would effect germplasm or gene transfers, polyploidy manipulations, and interspecific hybridization. Male sterility can be used to obtain more reliable estimates of gene action in quantitative and qualitative studies and as a tool in cytogenetic research. Either cytoplasmic or genic male sterility could be equally as effective for these purposes.

Either form of male sterility could be used for hybrid production, but, if available and workable, cytoplasmic male sterility would be more useful for this purpose. Since seed production is of little concern to the grower of forage crops, a restorer system is not imperative. Schemes outlined for the production of hybrid sugar beets (22, 23, 24, 25, 26) or onions (16) via cytoplasmic male sterility are workable models available to the forage legume breeder. The first phase of a hybrid program is to incorporate cytoplasmic male sterility into desirable germplasm and to test breeding stocks. The second phase would probably be the development of topcross hybrids followed by production of single crosses (provided adequate seed can be obtained). Finally, either 3-way or 4-way (double cross) hybrids would be developed. The production of 4-way hybrids is dependent upon a functional restoration system or the union of cytoplasmic and genic male sterility. The expression of cytoplasmic male sterility is quite often influenced by the environment. This lack of stability will be a cause of concern to the breeder. The absence of pollen on male steriles will discourage bee visitation to effect seed set. Selection for high seed set and for desirable pollinating insects will present still further problems to the breeder. In addition, users of cytoplasmic male sterility must be concerned with the genetic stability of sterile cytoplasms, pleiotropic effects of sterile cytoplasm, pleiotropic effects of fertility restorer loci (if used), and proper indexing of male sterile and restorer lines (13). The proposed schemes are somewhat limited if an effective incompatibility system is operative in the species. Failure of seed to set on 50 percent of the plants will be realized after limited backcrossing.

Hybrids can be produced using genic male sterility in the conventional manner (this requires roguing male fertiles at anthesis), in union with genetic

markers (unless completely linked, recombinations will occur and give some misclassification and a need for final inspection at anthesis), or by pseudo male sterility (male sterility in one environment but fertile in second--difficult to control environments to give complete control of male fertility).

One would suspect that either cytoplasmic or genic male sterility or both are operative in most species, and, if the appropriate effort is extended, it can be located. When located, it can be utilized in the breeding of forage legumes. Economics may dictate that hybrid production is not feasible in some species. On the other hand, male sterility can be used effectively in almost all species, in either basic or applied studies, to understand the nature of gene action and to effect germplasm or gene transfer.

Literature Cited

1. Binek, A. and E. T. Bingham. 1970. Cytology and crossing behavior of triploid alfalfa. *Crop Sci.* 10:303-306.
2. Bingham, E. T. 1968. Transfer of diploid Medicago spp. germplasm to tetraploid M. sativa L. in 4x-2x crosses. *Crop Sci.* 8:760-761.
3. _____, and A. Binek. 1969. Hexaploid alfalfa, Medicago sativa L.: Origin, fertility and cytology. *Can. J. Genet. Cytol.* 11:359-366.
4. Bond, D. A., J. M. Drayner, J. L. Fyfe, and G. Toynbee-Clark. 1964. Male sterility in field beans (Vicia faba L.). *J. Agr. Sci.* 63:229-234.
5. Bradner, N. R. and W. R. Childers. 1968. Cytoplasmic male sterility in alfalfa. *Can. J. Plant Sci.* 48:111-112.
6. Childers, W. R. 1952. Male sterility in Medicago sativa L. *Sci. Agr.* 32:351-364.
7. _____, and H. A. McLennan. 1960. Inheritance studies of a completely male sterile character in Medicago sativa L. *Can. J. Genet. Cytol.* 2:57-65.
8. Davis, W. H. 1968. Male sterile hybrid program. Rept. 22nd Alfalfa Imp. Conf. July 9-11. Reno, Nevada.
9. _____ and I. M. Greenblatt. 1967. Cytoplasmic male sterility in alfalfa. *J. Hered.* 58:301-305.
10. Dudley, J. W. 1963. Effects of accidental selfing on estimates of general and specific combining ability in alfalfa. *Crop Sci.* 3:517-519.
11. Duvick, D. W. 1959. The use of cytoplasmic male sterility in hybrid seed production. *Econ. Bot.* 13:167-195.

12. Duvick, D. M. 1966. Influence of morphology and sterility on breeding methodology. pp 85-138. Plant Breeding. Iowa State Univ. Press.
13. _____. 1968. Use of male sterility in the breeding of outcrossing crops. Proc. XII Intern. Cong. Genet. Tokyo, Japan. 2:228-229.
14. Edwardson, J. R. 1967. Cytoplasmic male sterility and fertility restoration in Crotalaria mucronata. J. Hered. 58:266-267.
15. Ericksen, A. W. and J. G. Ross. 1963. Inheritance of colchicine-induced male sterility in sorghum. Crop Sci. 3:335-338.
16. Jones, H. A. and A. E. Clarke. 1943. Inheritance of male sterility in the onion and the products of hybrid seed. Proc. Amer. Soc. Hort. Sci. 43:189-194.
17. Knight, W. E. 1969. Inheritance of apetalous male-sterile character in crimson clover. Crop Sci. 9:94-95.
18. Leonard, W. H., R. M. Love, and M. H. Heath. 1968. Crop terminology today. Crop Sci. 8:257-261.
19. Loper, G. M. and G. D. Waller. 1970. Alfalfa flower aroma and flower selection by honey bees. Crop Sci. 10:66-68.
20. Mackensen, O. and W. P. Nye. 1969. Selective breeding of honeybees for alfalfa pollen collection: Sixth generation and outcrosses. J. Apic. Res. 8:9-12.
21. McWhirter, K. S. 1969. Cytoplasmic male sterility in Desmodium. Aust. J. Agr. Res. 20:227-241.
22. Owen, F. V. 1948. Utilization of male sterility in breeding superior yielding sugar beets. Proc. Amer. Soc. Sugar Beet Technol. pp 156-161.
23. _____. 1950. The sugar beet breeder's problem of establishing male-sterile populations for hybridization purposes. Proc. Amer. Soc. Sugar Beet Technol. pp. 191-194.
24. _____. 1952. Mendelian male sterility in sugar beets. Proc. Amer. Soc. Sugar Beet Technol. 7:371-376.
25. _____. 1954. Hybrid sugar beets made by utilizing both cytoplasmic and Mendelian male sterility. Proc. Amer. Soc. Sugar Beet Technol 8:64.
26. _____, A. M. Murphy, and G. K. Ryser. 1946. Inbred lines from curly-top resistant varieties of sugar beets. Proc. Amer. Soc. Sugar Beet Technol. 246-252.
27. Pedersen, M. W. and R. E. Stucker. 1969. Evidence of cytoplasmic male sterility in alfalfa. Crop Sci. 9:767-770.

28. Putt, E. D. and E. B. Heiser, Jr. 1966. Male sterility and partial male sterility in sunflower. *Crop Sci.* 6:165-168.
29. Sampson, D. R. 1966. Linkage of genetic male sterility with a seedling marker and its use in producing F_1 hybrid seed of Brassica oleracea (cabbage, broccoli, kale, etc.). *Can. J. Plant Sci.* 46:703.
30. Sanchez-Monge, E. 1968. Use of male sterility in plant breeding. *Proc. XII Intern. Cong. Genet.* Tokyo, Japan. II:224-225.
31. Smith, R. R. 1968. Inheritance of a male sterile character in red clover, Trifolium pratense L. *Agron. Abstr.* 1968:22.

The Application of Cytoplasmic and Genetic Sterility in Gramineae Improvement

Glenn W. Burton
USDA, ARS, CR, Tifton, Georgia

Sterility in plants may result from chromosome imbalance or direct genetic and cytoplasmic effects. Sterility resulting from chromosome imbalance usually affects both male and female organs. Thus, it is of little use in grass improvement except where vegetative propagation of the F_1 hybrid is commercially feasible.

The problems associated with using genetic male-sterility in commercial F_1 hybrid seed production make hybrid seed so produced very costly. Thus, it is likely to be of little use in producing commercial F_1 hybrid grass seed unless the hybrids can be propagated vegetatively at low cost. Genetic male-sterility can be introduced into a population of a highly self-pollinated grass, such as barley or wheat, to make it behave more like a cross-pollinated species.

Cytoplasmic male-sterility does permit the production of F_1 hybrid seed at low cost and offers much promise as a mechanism for putting superior F_1 hybrids on the farm. Since it emasculates plants genetically and is under genetic control, it may be used to facilitate the production of vegetatively propagated hybrids as well as those that must be commercially grown from seed. It can be introduced into a self-pollinated population to make it cross-pollinated. It permits the closed pedigree that commercial seed companies associate with profits that accrue from the highly advertised "exclusive variety."

By using (B) non-fertility restoring males to produce commercial F_1 hybrids with CMS (A) females, the grass breeder can produce sterile F_1 hybrids. These hybrids may have quality advantages over their fertile counterparts. The farmer who grows them will not be tempted to save his own seed. But most important, these hybrids will not possess the weed potential of a fertile seed-producing grass. Had non-fertility restoring males been used in the production

of sorghum-sudangrass hybrids, the serious weed problem resulting from these hybrids volunteering in corn fields could have been avoided.

I believe that cytoplasmic male-sterility can be found in every species. In corn, pearl millet, and sorghum, cytoplasmic male-sterility results from the interaction of a homozygous recessive ms gene in a special "sterile" cytoplasm. Fertility is restored by the dominant MS gene. Thus, in a cross-pollinated grass, one is much more likely to find cms plants in an S_1 population than in one that is open-pollinated. Since there is evidence to indicate that wide crosses are most apt to yield cms plants, F_2 progenies of such crosses should be screened for male-sterile plants. Such plants should be hybridized with a number of marked fertile plants. A sterile F_1 will indicate that the sterile female parent was cms (A) and the marked fertile male parent was a maintainer (B). Other male parents giving fertile F_1 's on such a cms female must be fertility restorers (R). Fertile F_1 's from all crosses between male-sterile plants and marked males suggest genetic male-sterility or a high frequency of restorer (R) plants in the population.

Cms plants should be made isogenic with their maintainers through a series of backcrosses if seed-propagated F_1 hybrids is the ultimate objective in the breeding program. Such backcrossing will frequently improve male-sterility by reducing the number of modifiers that affect it. Since these male-steriles will be the producers of commercial hybrid seed, they must have good seeding properties. Screening potential maintainers for seed yield and quality before they are "sterilized" can save much time and effort.

Potential males of diverse origin should be screened first for such highly heritable characters as maturity and disease resistance. They must flower at the same time as the cms stocks to produce commercial hybrid seed. Hybrids between males passing these tests and the best cms stocks must then be made and screened for yield, fertility, quality, etc. Generally, males that do not restore fertility should be sought unless the seed will contribute significantly to the quality of the forage.

Commercial F_1 hybrid seed can be produced in the conventional manner by harvesting seed from the (A) strips in fields planted to alternate strips of cms (A) and pollinator (B) lines.

The success of Gahi-1 pearl millet suggests that 100 percent hybrid seed is not required to give the full hybrid effect. I believe that the percent of male plants required to effectively fertilize the male-sterile females could be reduced considerably if they were uniformly dispersed throughout the seed field. Research currently underway at Tifton will help answer this question. Seed-production costs could be greatly reduced and seed yields could be increased by more than 25 percent if it were only necessary to harvest all seed from a field planted to a mixture of 95 percent (A) and 5 percent (B) lines.

By using dwarf or short cms (A) lines and tall (B) lines, it would be possible to remove most of the tall pollinator from an intimate (AB) mixture by mowing at a height that would clear the heads of the short (A) plants. This technique is also being studied at Tifton.

H. H. Rogers, grass breeder at Cambridge, England, told me recently that over 30 years of breeding perennial ryegrass in the world has not advanced forage yield. His observation would apply equally well to a number of other grass species. I believe forage yields and efficiency of dry matter production could be significantly improved if grass breeders would develop good commercial F_1 hybrids. Discovering and utilizing cytoplasmic male-sterility appears to be the best way of achieving this objective with species that are not apomictic and cannot be economically propagated by vegetative means.

The Future For Forage Crop Breeding

A. A. Hanson

USDA, ARS, CR, Beltsville, Maryland

Introduction

Research on perennial forage grasses and legumes has undergone a number of substantial changes during the past decade. These changes can be attributed to many factors, including new concepts in genetics and plant breeding, availability of research funds, assignment of research priorities, growth of privately sponsored research, and especially the projected role of perennial forages in U.S. agriculture.

In order to assess the current situation in these crops, we need to look, albeit superficially, at the development of forage research in the United States. Prior to the mid 1930's, forage breeding and management research was extremely limited, with major attention devoted to the introduction and testing of new accessions of grasses and legumes and to the distribution of seed for on-farm tests. Initially, great enthusiasm greeted attempts to breed improved varieties, an enthusiasm based primarily on the tremendous variation observed in space-planted nurseries of both the legumes and grasses. It seemed obvious that selection of superior phenotypes and the elimination of weak, unthrifty plants would produce immediate progress in yield and quality. The road to success, with some exceptions, proved to be more difficult than that visualized or projected at the outset of many research programs. It soon became apparent that effective selection could not be practiced in the absence of information on the nature of polyploidy, on mode of reproduction and breeding behavior, and on breeding and evaluation procedures applicable to perennial forages. It was also obvious that the degree of domestication of forage species achieved by man was far less than that in cereals and many other cultivated crops. In addition, some programs faltered because of limitations imposed by species selected for study, restricted germplasm, and lack of effective methods for producing and maintaining seed stocks and for promotion of new varieties. The development of improved management and soil fertility practices received recognition, but, in many regions, farmers' acceptance remained at relatively low levels. Lack of information on feeding value, forage handling, and total feeding systems for livestock production represented serious handicaps in forage extension programs. Indeed, the complexity of forage

research contributed to false starts and to examples of overt failure. Conversely, we can identify numerous achievements within individual forage species that rank with or exceed those attained in other crop plants.

It is not my intention to summarize forage research in the United States or to list locations where work is in progress. I will simply give you my impressions of where we stand today and mention some trends that could influence the future of forage research.

Genetic Diversity

Genetic diversity is basic to plant improvement. This statement is so self-evident that one wonders if it deserves attention in any report on forage research. In the forage grasses and legumes, however, we face peculiar problems that have not been appreciated thoroughly in some breeding efforts.

The most important species, with the exception of several range grasses, were introduced into the United States from foreign countries. There is evidence that some introduced species may trace to relatively few accessions that were not truly representative of available germplasm. Furthermore, there is a possibility that this problem may be more wide-spread within introduced grasses and legumes than most people realize. One possible explanation as to why this situation is not soon corrected rests with the comparatively rapid evolution of regional strains or ecotypes that result when a single introduction is grown and reproduced over a wide range of environmental conditions. Subsequent comparisons in nurseries and plot tests among these local ecotypes and more recent introductions will often favor the former. There is a tendency, therefore, to discard many introductions before they can contribute to our germplasm resources.

The emphasis placed on locally adapted ecotypes is not particularly serious insofar as the objective of a given program is to identify well-adapted seed sources. In practice, many local strains and ecotypes have been named and released on the basis of demonstrated superiority in vigor and/or persistence in comparison with imported seed lots and ecotypes from other regions. It is now recognized that the heavy elimination of newly introduced germplasm in preliminary screening tests may place severe limitations on progress in plant breeding. The practice is most restrictive if the plant breeder must confine himself to selecting within the limits of variation imposed by adapted ecotypes. Adapted ecotypes and named varieties where they are available may not possess sufficient variation for effective improvement in quality, multiple pest resistance, and significant changes in either growth habit or growth cycle.

Genetic diversity can be increased by intercrossing foreign introductions, local collections, and named varieties. Greenhouse crosses can be used where time of flowering or poor persistence would eliminate or curtail the contribution of new accessions to the interbreeding population. These broad-based populations provide an opportunity to preserve germplasm at relatively low cost and to achieve extensive recombination of genetic traits. In the interest of maintaining maximum diversity, the breeder may be well advised to apply

little or no selection to the population beyond that imposed by prevailing environmental conditions.

Broad-based germplasm pools developed in this manner can be subjected to mass selection to develop improved source materials, and they can be maintained as a reserve source of germplasm to which new accessions can be added at will. Both selected and unselected germplasm pools represent excellent source material for inclusion in screening tests whenever a breeding objective is added to an ongoing program. At present, serious thought is being given to developing broad-based regional germplasm pools in alfalfa, and, eventually, this concept could be extended to other major forage plants.

Breeding Methods

A comparative analysis of alternative forage breeding methods is beyond the scope of a brief paper. It would be appropriate, nevertheless, to examine some current approaches in forage breeding.

Selection methods: It is now recognized that "mass selection," which may have been discarded in favor of more sophisticated methods, can be extremely useful, especially in increasing the frequency of genes for desirable characteristics in germplasm pools. Factors affecting progress through mass selection include stage of breeding program, genetic characters sought, and the effectiveness of selection pressure applied.

"Recurrent selection" has gained in stature on the basis of demonstrated success in increasing the frequency of desirable genes. In simple terms, recurrent selection implies that each cycle of selection will be conducted within populations created by intermating selected plants from the previous cycle. Recurrent selection may be based entirely on phenotype in conjunction with mass selection but often includes replicated progeny tests of selected plants. Mass selection, and especially variations of recurrent selection, have demonstrated their value in developing alfalfa germplasm pools and varieties that possess multiple-pest resistance. Mass selection in most forages appears to be a logical forerunner to more sophisticated breeding methods, such as the development of hybrid alfalfa.

There is a growing realization that certain "good" breeding objectives may have unrecognized and perhaps undesirable side effects. In the search for insect tolerance in forages, questions arise with respect to response of animals feeding on insect resistant varieties. There is also the possibility that increased palatability and improved forage intake could result in toxicity when the original forage shows little or no evidence of creating animal toxicity problems. These and similar questions have encouraged the growth of cooperative research among geneticists, plant physiologists, biochemists, and animal nutritionists. It has been demonstrated, for example, that estrogenic activity in alfalfa is closely allied with damage from foliar diseases. The slobbering effect induced in cattle by some second-growth red clover hays is now known to be due to the black patch fungus (*Rhizoctonia leguminicola*) on the forage. To date, research results indicate that development of pest resistance has not adversely affected animal performance.

Isogenic lines are powerful tools in studying the overall effects of selection for specific characteristics. They were used to demonstrate that awnlessness in wheat is not compatible with maximum grain production. However, opportunities for developing and using either isogenic lines or populations are limited in the complex polyploids. On the other hand, there is evidence from other crop plants that forage breeders must be concerned not only with the development of more effective breeding methods and screening techniques but also with the study of changes, both desirable and undesirable, that may accompany intensive selection.

Inbreeding: The deleterious effects of inbreeding forages are well documented and, as a result, most workers have not looked with favor on inbreeding in the development of improved forage varieties. Some attention has been given to the use of inbred progenies in evaluating clonal selections and, more recently, to the characteristics of self-sterile vs. partially self-fertile selections within polyploid forage grasses. It has been concluded by E. L. Nielsen and P. N. Drolsom that there could be advantages within certain grasses in selecting plants that possess some fertility, even though low, rather than using wholly self-sterile selections. This conclusion is based on preliminary comparative tests, as well as on evidence that a modest degree of self-fertility is associated with greater meiotic chromosomal regularity. It is anticipated that chromosomal regularity offers greater opportunities for gene exchange and for the isolation of desirable recombinants. Findings on the interrelationship of self-sterility, partial self-fertility, and inbreeding suggest that we may have been overlooking some opportunities in the development of improved grass synthetics.

There is also evidence to suggest that inbreeding cannot be ignored in projecting the performance of narrow-based synthetics developed from comparatively few clonal selections of polyploid species. Many narrow based synthetic varieties exhibit resistance or tolerance to certain pests and uniform maturity, as well as other desirable characteristics. On the other hand, they may be somewhat restricted in region of adaptation and heterotic response may not reach desired levels. Although complete documentation is lacking, there is a growing body of evidence and opinion to suggest that we should move toward the use of a broader genetic base in synthetic varieties in order to maintain a higher level of heterozygosity.

Considerable attention has been devoted to self-incompatibility mechanisms in clover, with the thought that self-incompatibility alleles could be utilized in the production of hybrid varieties. It has been shown for some clovers that the amount of seed set in normally self-incompatible plants is influenced by environmental conditions. In alfalfa, self-incompatibility does not appear to be a reliable approach to pollination control because of sensitivity to environment. These findings emphasize the importance of defining environmental conditions where self-incompatibility would be of little consequence. There is also the prospect of isolating plants in which self-incompatibility is a highly stable characteristic.

Hybrid varieties: It is commonly thought that many breeding problems would vanish if we could control pollination in the cross-fertilized forages. In

fact, forage plant breeders have looked with envy at the progress achieved with hybrid varieties in other crops in which emasculation is practical or where usable sources of male sterility have been isolated. They have also looked at the remarkable growth and vigor of sterile hybrids in bermudagrass and wondered about techniques for achieving similar progress with seed propagated varieties.

Recently, cytoplasmic male sterile alfalfa lines have been used to develop experimental alfalfa hybrids, and one seed company has released a hybrid variety for commercial use. Although data are limited, several hybrids appear reasonably promising in comparative tests.

The enthusiasm with which we might regard the future of hybrid alfalfa and hybrids in other forage species must be tempered by several questions that can be directed toward hybrid forage varieties. We cannot be content with breeding alfalfa hybrids solely for yield potential. In the Midwest, we need only look at 10-ton alfalfa yields obtained with currently available adapted varieties and good management practices. Combining male sterility with pest resistance and persistence creates additional complexity and cost to breeding. In insect-pollinated forages, we find that seed set is lower on cytoplasmic male-steriles than on pollen-producing lines. Furthermore, theoretical genetic models indicate that it may be more difficult to attain maximum heterosis in autotetraploids than in diploid species. There are also questions regarding the range of adaptation of hybrid varieties, both regionally and to variable soil and management conditions encountered on individual farms.

Although usable sources of male sterility have not been isolated in perennial forage grasses, one can speculate on the advantages that might accrue from the development of hybrid orchardgrass. One objective in cool-season grasses includes the development of hybrids that would be more responsive to nitrogen than available varieties. Unfortunately, the limiting factor in many cool-season grasses is lack of persistence when grown at high nitrogen levels. It seems rather presumptuous to assume that persistence under intensive use would be improved simply by the development of hybrid varieties. Thus, the development of successful hybrids within certain species may have to be preceded by intensive selection for improved persistence at high levels of soil fertility.

The preceding questions do not mean that we should ignore cytoplasmic male sterility in alfalfa or forget the prospect of isolating usable male-sterile stocks in other forages. In fact, there are strong arguments for pursuing the development of hybrid varieties and for increasing the efficiency with which hybrids can be produced. Cytoplasmic male sterility offers promise in developing a series of varieties each adapted to a specific ecological niche. In addition, pollination control achieved in hybrid varieties could help to reduce the problem of genetic drift that is associated with the multiplication of synthetic varieties. Hybrids may serve also as a tool in variety protection. The value of research on hybrid forage grasses is supported by the superior vigor and yield of hybrids in diploid bahiagrass developed by intercrossing good combining self-sterile clonal lines. In the final analysis, the success of hybrids will depend on their relative pest resistance, yield, and quality in comparison with available synthetic varieties and with those synthetics that will be developed in the future.

Apomixis: Apomixis or asexual seed set was regarded by some investigators as an evolutionary "deadend" because of the obvious limitations imposed on recombination and segregation. It has become apparent, however, that apomixis in perennial grasses is an effective evolutionary force both in the creation and maintenance of new species under highly competitive conditions. In facultative apomictic species, variability is stored and released by means of the delicate competitive balance between sexual and apomictic embryo sacs in the same ovule. In these species environmental conditions can influence the relative proportions of sexual and apomictic seed. Environmental effects, together with the frequent fertilization of unreduced eggs, restrict the value of most genetic analyses. Although inheritance studies have been inconclusive, there appears to be little question regarding the existence of genetic control over the basic processes governing apomixis.

Obligate apomixis by definition would not seem to lend itself to inheritance studies. On the other hand, hybrids have been produced between sexual and apomictic species found within certain genera that belong to various "species complexes." Many or most hybrids from these wide crosses result from the fertilization of unreduced female with reduced male gametes.

Genetic data have been obtained by crossing obligate apomicts with closely related sexual biotypes. These studies have the advantage that the parent plants are capable of only one method of reproduction (apomixis vs. sexuality) and there is no evidence that obligate apomixis is influenced by environmental effects. Thus, it has been demonstrated by G. W. Burton and Ian Forbes that apomixis in common bahiagrass (Paspalum notatum) is recessive to the sexual state and controlled by a few recessive genes. Similarly, the inheritance of apomixis is relatively simple in buffelgrass (Cenchrus ciliaris). In this species, E. C. Bashaw and his associates concluded that mode of reproduction appears to be controlled by two genes and epistasis.

Hybridization of obligate apomicts with sexual plants provides an opportunity to develop new vigorous recombinations that can be stabilized and increased via apomixis. Higgins buffelgrass is the first apomictic variety produced through the manipulation of obligate apomixis. According to E. C. Bashaw, this variety possesses characteristics not observed previously in naturally occurring populations of C. ciliaris.

Information on the inheritance of apomixis and on opportunities for developing superior varieties by crossing apomictic and sexual biotypes has been most encouraging. These findings suggest that a better understanding of mechanisms responsible for apomictic seed set could enable plant breeders to induce or manipulate this process in other species. If this were achieved, it could become possible to develop vigorous hybrids that would remain true breeding through asexual seed set.

Interspecific and intergeneric hybridization: The contribution of hybridization to variation within forage species is well recognized, and extensive introgression has been reported within certain grasses. The study of genome relationships in hybrids and some extensive biosystematic investigations have been most helpful in clarifying taxonomic problems. On the other hand, it has

been learned that pairing relationships must be interpreted with care, for there is a possibility that chromosome pairing may be under genotypic control.

The ease with which many grasses can be hybridized has presented an interesting challenge to geneticists and plant breeders. It is equally obvious that the production of viable hybrids does not necessarily mean that such hybrids will contribute to population diversity. In general, the products of wide crosses will contribute to population diversity only when hybridization is followed by some form of chromosome doubling.

Ryegrass (Lolium spp.)-fescue (Festuca spp.) hybrids have received more attention from forage grass breeders than any other wide cross. Currently, research on various ryegrass-fescue hybrids is in progress in the United States, United Kingdom, Germany, The Netherlands, and France. Workers at these various locations have met with considerable success, but they have yet to solve the problem of producing stable, fertile plants that combine the best features of both species.

There is every reason to expect that some measure of success will be achieved in these programs, for they have yet to exhaust all available alternatives. R. C. Buckner at Lexington, Kentucky, was the first to develop a substantial number of amphiploids ($2n=56$) by doubling the chromosome number of sterile F_1 hybrids produced by crossing annual ryegrass ($2n=14$) with tall fescue ($2n=42$). A fair degree of fertility was achieved in amphiploids, but stability remains a serious problem. It seems conceivable that further selection will yield hexaploid ($2n=42$) hybrid derivatives that will retain portions of ryegrass chromosomes. The rate of exchange among ryegrass and fescue chromosomes is thought to be limited; thus, large numbers of hybrids will be needed so that ryegrass characteristics can be accumulated at the hexaploid level ($2n=42$) through recurrent selection.

Although exceptions may and will occur, it is safe to say that the use of wide crosses in breeding requires great patience. In many of these programs the investigator will not be greeted with instant success. It is entirely possible that he may have to accept comparatively small, difficult to recognize exchanges among chromosomes, and devote much time to accumulating these transfers in an acceptable, fertile type. Ryegrass-fescue crosses are apparently typical of those interspecific and intergeneric F_1 hybrids where there is little or no natural recombination of characters. The tendency of crosses of this nature to segregate toward the parental types in the absence of recombination or interchange mechanisms is well known.

Sterility problems can be readily circumvented in bermudagrass (Cynodon spp.) and in other species where the sterile products of wide crosses can be propagated vegetatively. Likewise, wide crosses that involve facultative apomicts provide an opportunity to select hybrids that produce seed asexually.

Another promising alternative is available where chromosome races exist within the same species complex. This has been demonstrated by D. R. Dewey who produced vigorous, fertile tetraploid hybrids by crossing Agropyron desertorum ($2n=28$) with induced tetraploids of A. cristatum. The induced tetraploids

were obtained by colchicine treatment of open-pollinated seed from diploid Fairway wheatgrass.

Interspecific hybridization has been discouraging in the Leguminosae. A notable exception is the transfer of low coumarin from Melilotus dentata to the agronomically important M. alba. These hybrids were grown to maturity by grafting them onto stocks of M. alba plants. In recent years progress has been made in developing hybrids of the Trifolium spp. Much of this success can be attributed to improved techniques for growing hybrid embryos and hybrid seedlings, and by increasing the diversity of parental species involved in crossing programs. Although it is much too early to evaluate the practical contribution of these investigations, they offer promise for the development of clovers characterized by improved persistence and pest resistance.

Induced polyploids: The intensive study of polyploidy in plant improvement began with the discovery that colchicine, an alkaloid found in the autumn crocus, could be used to double the chromosome number. Generally, induced autopolyploids have been most successful in crops grown for their vegetative parts rather than for seed, especially if they have a low chromosome number and are cross- rather than self-fertilized. Rather good autopolyploids have been obtained by doubling the chromosome number of sugarbeet, turnip, mangel, rye, mustard, red clover, alsike clover, ryegrass, grape, and a number of flowers.

Different genotypes within a species may react differently to chromosome doubling, and for this reason success is often associated with the number of induced polyploids available for study. In addition, "new polyploids" are rarely, if ever, successful without further selection for improved stability and fertility. Cross pollination of newly created polyploids provides opportunities for the recombination of genes conditioning fertility and genotypic balance.

In groups of natural species characterized by differences in level of polyploidy, artificially induced polyploidy may serve as a step in transferring a valuable characteristic from one species to another across the barrier of hybrid sterility. In addition, sterile hybrids between distantly related species have been rendered fertile by doubling the chromosome number (amphiploidy). As a rule, these artificial allopolyploids have been less successful than induced autopolyploids. They are often distinguished by extremes in genic sterility, unstable chromosome numbers, and the preferential segregation of chromosome sets or genomes. Recent work in Wisconsin and Canada indicates promise for isolation and use of natural hexaploids of alfalfa for theoretical and applied research. Hexaploid forms apparently arise from the union of reduced (2x) and unreduced (4x) gametes. It is fair to state that polyploid breeding is a specialized approach with demonstrated merit in certain species.

Induced mutations: Mutation breeding based on the treatment of grasses and legumes with chemical mutagens and ionizing radiation is somewhat controversial. However, the potential value of induced mutations is supported by the obvious value of natural somatic mutations in developing successful varieties of many fruits and flowers. Research has shown that there are no essential differences between induced and spontaneous mutations.

Mutation breeding could well receive consideration when conventional breeding procedures show little evidence of success, where a large sample of plant material can be irradiated and tested, and where screening procedures for the characteristic under consideration are highly effective. Individual investigators must decide whether mutation research or some other method of increasing variability is applicable to the species with which they are working. In these deliberations, attention must be given to the variability available in plant collections and to the variability that can be created in germplasm pools.

Multiplication of Improved Varieties

The multiplication of improved varieties of alfalfa, clovers, and grasses present several problems peculiar to the largely cross-fertilized forage species. Since these species are grown for their vegetative parts, seed production has become a specialized industry often concentrated in regions where environmental conditions are favorable to high yields of good quality seed. Seed production in areas far removed from intended areas of seed usage for forage has focused attention on the dangers of genetic changes in varietal composition during seed multiplication.

It has been demonstrated that dramatic changes in genetic composition can occur when comparatively heterozygous varieties are grown for seed in areas that differ appreciably in latitude, day length, and prevailing temperatures. Many of these genetic shifts have been associated with genotype-environment interactions and resulting changes in time and amount of flowering and relative seed yield of various genotypes. Rate of change can be accentuated by differential winter damage as well as by disease infestations and insect damage.

Genetic shift results from the same selective forces that give rise to ecotypes. Thus, changes in varietal composition can be induced by differential management practices at the location where the variety was developed and in fields where the variety is grown for seed. Time of harvest and seedling yield production are important sources of variation if all genotypes do not contribute equally to seed yield. The breeder must assume the responsibility for defining management practices that will minimize genetic change.

Genetic shift can be controlled by stipulating for each variety the region in which seed can be grown, the number of generations of seed increase within and outside the region of forage adaptation, acceptable management practices, adequate isolation distances, and approved levels of protection from volunteers and mechanical mixtures. A continuing need remains to define conditions under which seed of new varieties can be produced without serious change, and for developing rapid, reliable methods for identifying genetic changes in the largely cross-fertilized forages. Although great strides have been made in improving production efficiency, opportunities exist for additional progress through improving pest control practices, productive life of seed fields, and effectiveness of pollinating insects, in reducing seed losses in harvesting, and in controlling undesirable volunteers.

Future Trends

The future of forage breeding research will be determined largely by available research resources. There is every reason to expect that private seed companies will expand their investment in applied forage crop breeding, and this trend will affect breeding programs conducted by public agencies. Additional information on the possible interaction of public vs private research in plant breeding is included in my comments on the "Plant Variety Protection Act." At this point, I would draw your attention to three aspects of private forage crop breeding programs that warrant attention:

1. Most private research involves selection in the region of seed usage, measuring seed yield potential and multiplying experimental seed lots in seed-growing areas, and the evaluation of experimental varieties in the region or regions of eventual use. In general, private programs have realized a better integration of seed and forage evaluation than that achieved in many publicly sponsored programs.

2. Privately supported varieties enjoy decided benefits from well-planned seed production schedules, advertising and promotion campaigns, and established wholesale and retail outlets.

3. The growth of privately sponsored forage breeding programs is a healthy sign and should be welcomed by all those concerned with the improvement of these crops. It is reasonable to assume, however, that private breeding programs will involve comparatively few forage grasses and legumes, with emphasis given to species where seed usage warrants a substantial investment.

There is no doubt that both private and public forage breeding research will be influenced by trends in forage production and livestock feeding practices. Again, I will have an opportunity to expand on this topic in my discussion on the "Future Role of Forages in Cattle Production."

We have never been in a better position to define forage problems or to design research for the solution of these problems. Nevertheless, there is cause for concern over the current research base in forage breeding and the lack of organized support for either program expansion or for the maintenance of existing research programs. This situation indicates that recent trends in the use of perennial grasses and legumes may not be reversed in the immediate future. The long-term outlook in forage breeding is favorable in terms of potential for improvement, and in terms of current research designed to improve the competitive position of these valuable species. Conversely, the immediate outlook for substantial increases for publicly supported grass and legume breeding research is not encouraging. Inflation, social programs, and national priorities have reduced the status of agricultural research, and forage breeding may be vulnerable with an overall retrenchment in agricultural research. We may find that some portion of our breeding and genetic research may have to be justified on the basis of pollution control and waste disposal rather than in terms of animal products.

We must take a hard look at priorities in forage breeding programs in order to insure the continuance of those projects that will produce germplasm and data most urgently needed in the years ahead. Insofar as resources permit, we should devote special attention to the following:

1. The need to assign special attention to collecting and preserving germplasm resources, developing germplasm pools, devising more reliable techniques for restoring fertility and stability to the sterile products of wide crosses, determining the origin of apomixis and its potential for manipulation, induction of haploidy, isolating usable sources of cytoplasmic male sterility, improving seed set of male sterile lines of insect-pollinated species, and nature of heterosis in autotetraploids.

2. The need to improve our understanding of the interrelationships among biochemical processes, environment, and growth, and thereby provide principles to guide the development of superior grasses and legumes.

3. The need to develop rapid, highly repeatable techniques for evaluating large individual-plant populations for components of biological efficiency, forage quality, pest resistance, and tolerance to environmental hazards.

4. The need to improve intake and digestibility of grasses and legumes through breeding. Techniques have been developed for predicting quality from small forage samples, and, while these techniques can be improved, they are being used to evaluate management practices and to select for improved quality. Thus, G. W. Burton and his associates used nylon bags to measure dry matter disappearance of forage samples in selecting Coastcross 1 bermudagrass. This improved variety is comparable to Coastal in yield and 11 to 12 percent above Coastal in digestibility. This difference in digestibility has produced 30 percent better daily gains in cattle. Animal acceptance was used at Woodward, Oklahoma, to select 'Morpa' weeping lovegrass. This variety, developed and evaluated by P. W. Voigt, E. H. McIlvain, and others, has produced 11 to 12 percent higher liveweight gains than common weeping lovegrass. These two illustrations represent exciting examples of what can be achieved through breeding.

What is a Variety?

S. F. Rollin
USDA, CMS, Beltsville, Maryland

Definition of Variety Under the Federal Seed Act. The term "variety" means a subdivision of a kind which is characterized by growth, plant, fruit, seed, or other characters by which it can be differentiated from other sorts of the same kind; for example, Marquis wheat, Flat Dutch cabbage, Manchu soybeans, Oxheart carrot, and so forth.

International Code of Nomenclature. The international term "cultivar" denotes an assemblage of cultivated plants which is clearly distinguished by any characters (morphological, physiological, cytological, chemical, or others) and which, when reproduced (sexually or asexually), retains its distinguishing characters.

You will note that the distinguishable characters referred to in this definition are required to be retained when reproduced sexually or asexually.

Kinds of cultivars (varieties) are listed as follows:

a. A clone, consisting of uniform material derived from a single individual and propagated entirely by vegetative means as, for instance, by cuttings, divisions, grafts, etc.

Example: Cynodon dactylon, "Coastal"

b. A line, consisting of sexually reproducing population of uniform appearance, propagated by seeds or by spores, its stability maintained by selection to a standard.

Example: Triticum aestivum, "Marquis"; Zea mays, "Wisconsin 153A"

c. An assemblage of individuals (reproducing sexually or by apomixis) showing genetical differences but having one or more characteristics by which it can be differentiated from other cultivars (varieties).

Example: Medicago sativa, "Ranger," the breeder seed of which is derived from intercrossing five seed-propagated lines each maintained under isolation.

d. A uniform group which is a first generation hybrid (F_1) reconstituted on each occasion by crossing two or more breeding stocks maintained either by inbreeding or as clones.

Example: Sorghum "Texas 610"; maize "US 13", a double-cross involving four inbred lines.

Plant Variety Protection Act. The term "novel variety" may be represented by, without limitation, seed, transplants, clones, and plants, and is satisfied if there is:

(1) Distinctness in the sense that the variety clearly differs by one or more identifiable morphological, physiological, or other characteristics as to which a difference in genealogy may contribute evidence, from all prior varieties of public knowledge at the date of determination within the provisions of section 42; and

(2) Uniformity in the sense that any variations are describable, predictable, and commercially acceptable; and

(3) Stability in the sense that the variety may be sexually reproduced with its distinctive characteristics with a reasonable degree of reliability, or to a degree comparable to that of other varieties of the same kind.

The 1961 Paris Convention for the Protection of New Varieties of Plants.

A new variety may be defined and distinguished by morphological or physiological characteristics. In all cases, such characteristics must be capable of precise description and recognition.

The new variety must be sufficiently homogenous, having regard to the particular features of its sexual reproduction or vegetative propagation.

The new variety must be stable in its essential characteristics; that is to say, it must remain true to its description after repeated reproduction or propagation or, where the breeder has defined a particular cycle of reproduction or multiplication, at the end of each cycle.

Ad Hoc Committee of Federal and State Officials and Plant Breeders. The definition of a variety is understood to include the following categories and types:

A. Clonal varieties. Consist of one clone or several closely similar clones which are propagated by asexual means; for example, by cuttings, divisions, grafts, or obligate apomixis.

B. Self fertilizing varieties

(1) Variety. Derived from breeder seed consisting of one or more similar lines of self-fertilizing plants or inbred lines of normally cross-fertilizing plants.

(2) Multiline variety. Derived from breeder seed consisting of two or more experimental lines which are similar in most characteristics but differ in a limited number of major characteristics of economic importance.

C. Cross-fertilizing varieties. Consist of cross-fertilizing plants which may show genetical differences but having one or more characters by which they can be differentiated from other varieties.

- (1) Variety. Derived from breeder seed which is reconstituted by mass selection to assure retention of described characteristics.
- (2) Syn-1 variety (first generation synthetic variety). First-generation progenies derived and reconstituted for each generation of the commercial seed class by intercrossing the same set of selected clones or seed lines.
- (3) Synthetic variety. Advanced-generation (beyond Syn-1) progenies derived from intercrossing the same set of selected clones or seed lines.

D. Hybrid varieties. First generation progenies resulting from a cross produced by controlling the pollination and by combining (1) two or more inbred lines; (2) one inbred or a single cross with an open-pollinated variety; or (3) two selected clones, seed lines, varieties, or species. "Controlling the pollination" means to use a method of hybridization which will produce pure seed which is at least 75 percent hybrid seed.

- (1) Hybrid (pure). Hybrid seed constitutes at least 95 percent of pure seed.
- (2) Hybrid (with qualifications). Hybrid seed constitutes at least 75 percent but less than 95 percent of pure seed; labeling requirements are (1) percent of hybrid seed must be specified or (2) statement "contains 75 percent to 95 percent hybrid seed."

A blend is a mixture of two or more varieties of seed each present in excess of 5 percent.

Plant Variety Protection

A. A. Hanson
USDA, ARS, Beltsville, Maryland

The development of plant variety protection legislation has had a very interesting history in the United States. The bill providing for plant variety protection, S.3070, is now under consideration by appropriate sub-committees in the House and Senate. There is every expectation that the bill will be passed by Congress.

I will sketch the development of plant variety protection in other countries, the steps that led to current legislation in the United States, the nature of the protection afforded by this proposed legislation, and conclude with some general comments on what this legislation could mean to public and private plant breeders.

Various schemes for providing plant breeders' rights have been adopted in Europe. The system that prevails in Holland, and is incorporated in their Plant Breeders' Decree of 1941, will serve as an example of procedures used to procure plant breeders' rights in Europe^{1/}. Thus, in Holland, legal breeders' rights can only be secured on varieties entered in the Central Register of Varieties. For this purpose, the variety must be (1) new (that is, sufficiently definable and reproducible in its main characteristics) and different from any other variety of which, at the time of application, propagating material is already available for sale at home or abroad, or for which entry in the Central Register has been applied for or obtained, and (2) sufficiently homogenous.

For those varieties of cross-pollinating agricultural crops which are unable to secure entry to the Central Register, but which, nevertheless, are included in the compulsory list of varieties, the breeders concerned have the exclusive right to supply certified seed and other propagating material. The use of uncertified seed is not permitted.

Novelty tests required for registration are conducted by either the State Institute for Research on Varieties of Field Crops or by the Institute for Horticultural Plant Breeding. Depending on the crop, these trials may take from 1 to 3 years.

Plant breeders' rights are granted for novelty and not cultural value. The seed control provisions in the 1941 Decree, however, stipulate that only seeds and seed potatoes of varieties of agricultural crops entered in the latest (annual) issue of an Official List of Varieties may be sold in Holland. Entry to this list is granted, after suitable trials, only to varieties considered of special value to Dutch Agriculture. For admission to official lists, a variety is expected to be better than existing varieties in at least one

^{1/} Plant Breeders' Rights. Report of the Committee on Transactions in Seeds. July 1960.

important character. There also are lists of varieties of horticultural crops, but they are advisory and not compulsory, and varieties other than those listed can be sold. Tests for value are conducted by the same institutes that judge novelty and normally run from 1 to 2 years. Inferior varieties are discarded at this stage, and additional testing is conducted by the Advisory Services.

The Advisory Services conduct provincial trials for 1 or 2 years on surviving varieties. In 1959, it was estimated that from 40 to 50 acres were devoted to value trials at the State Institute for Research on Varieties of Field Crops at Wageningen and a further 100 acres to provincial trials. In the same year, the testing of horticultural crops for which there is no compulsory list of varieties involved some 35 acres at Wageningen and an additional 100 acres at Elst. The entire cost of novelty tests is covered by a fee system, but there is no charge to breeders for the inclusion of their varieties in value tests. The 1941 Decree protects names of varieties entered in the Central Register or Official List. For varieties of ornamental crops, the breeder's right is operative for 17 years, with the possibility of extension. For other horticultural and agricultural varieties, the initial period of protection is 25 years, with the possibility of extension for successive terms of 10 years.

In Europe, protection systems vary from country to country. It is generally true, however, that varieties of many cultivated plants obtained by selective breeding are eligible for the granting of rights provided the variety is (a) distinct, (b) stable, and, in some countries, (c) of agricultural or horticultural value. The protection systems are tied to Official Catalogues of Varieties or Official Lists. Thus, protection on the basis of novelty alone is no guarantee that seed or propagating material of the variety can be sold in the country of origin.

In contrast with Europe, the only breeders' rights that have been available in the United States are those offered under the Plant Patent Act of 1930. According to this act, a breeder or discoverer of a new and distinct variety of an asexually reproduced plant, other than a plant which is tuber-propagated or found in an uncultivated state, may be granted a patent. Broadly speaking, the Act covers plants which are reproduced vegetatively (except for tubers) but not those reproduced by seed. The granting of a patent is based solely on novelty and distinctness as established by documents, drawings, etc., as in the case of patents for industrial inventions. No trials are conducted, and, therefore, there are no substantial demands on the Government for manpower and funds. The granting of a patent does not imply any Government endorsement of quality or merit, and the Patent Office publishes a warning to that effect. Licenses are granted to established business firms to reproduce only, to reproduce and sell, and to grow for cut flowers. The period of protection is 17 years, and there is no provision for extension.

The need to improve national variety protection schemes was considered at the Swedish meeting of the International Conference on Seed Production, Testing, and Distribution in 1954. Recommendations developed at this conference prompted the French Government to sponsor meetings on plant protection. Proposals from these meetings were incorporated in proceedings entitled "The

Convention of Paris for the Protection of New Varieties of Plants," December 2, 1961^{2/}. The Paris Convention attempted to provide guidelines for the registration of protected varieties as an essential step toward improved reciprocity in plant protection systems. Requirements for registration adopted by the Paris Convention specified that: (1) the new variety must be clearly distinguishable by one or more important characteristics from any other known variety; (2) it must be sufficiently homogenous in important characters; (3) it must be stable in its essential characteristics after repeated reproduction; and (4) it must be properly named. The Paris Convention does not require merit as a criterion for the registration of varieties. As mentioned, several countries develop Recommended or Restricted Lists of Varieties that through official tests have been found to have cultural value within their borders. The Paris Convention does not prohibit a country from adopting utilitarian measures, but such provisions are not a part of the convention.

More recently attempts have been made to standardize the characters that can be used to distinguish new crop varieties. A January 1970 report from an European technical working group for self-fertilized cereals, lists the following number of distinguishing characters proposed for barley, oats, wheat, durum wheat, and rice; namely, 23, 19, 34, 44, and 23, respectively. According to this working group report, characters would be determined from 200 ear rows and, with few exceptions, recorded on a scale from 0 to 9.

In the mid-1960's breeders' rights became a prime topic of discussion at workshops, conferences, and professional meetings in the United States. Interest was stimulated by: increased activity of private plant breeders; escalating costs in older commercial breeding projects, as well as in newly established programs; the expansion of breeders' rights legislation in Europe; and the publicity arising from the Paris Convention on Plant Protection. Various facets of variety protection were considered in a symposium on "Analysis of Plant Breeders' Rights" held during the Crop Science Society of America meetings in Denver, Colorado, November 18, 1963^{3/}. This symposium was cosponsored with the American Society for Horticultural Sciences, the American Seed Trade Association, the International Crop Improvement Association (now AOSCA), and the National Council of Commercial Plant Breeders.

A second national symposium on "Variety Protection by Plant Patents and Other Means" was held during the American Society of Agronomy meetings, New Orleans, Louisiana, November 14, 1968. It would be impossible to summarize the diversity of opinion expressed at these symposia and at the various meetings that have not been cited.

Individuals engaged in public plant breeding programs were concerned by the possible effects of plant protection schemes on the free exchange of germplasm that has characterized plant breeding work in the United States. Some expressed doubt over delays that might be encountered in release of improved

^{2/} Weibull, Gunnar H. W. Breeders' Rights Systems in Europe. Amer. Soc. Agron. Spec. Publ. 3. March 1964.

^{3/} Plant Breeders' Rights. Amer. Soc. Agron. Spec. Publ. 3. March 1964.

varieties if official registration were an integral part of an approved plant protection program. Public plant breeders and administrators who agreed in principle that entrepreneurs should have some form of protection for their varieties were worried that the costs involved in administering a breeders' rights program would reduce rather than stimulate the development of new germplasm resources. Similarly, seedsmen were far from unanimous in their opinions on breeders' rights. The major positions expressed by seedsmen have been summarized by Allenby White^{4/} as follows: (1) some seedsmen, particularly those like garden seed breeders who have had many years of experience in breeding and marketing varieties were against or, at least, extremely wary of breeders' rights (a system of self-policing characterizes this segment of the seed industry, and they are proud of their capability to protect each others' varieties in the United States); (2) other seedsmen, particularly those engaged in breeding and marketing F₁ hybrids, regarding any artificial system of breeders' protection as less effective than the biological protection that they had at their disposal; (3) still others, particularly those seedsmen who had embarked on new breeding programs, recognized the value of breeders' rights, providing that the benefits of protection could be had without unreasonable Government intrusion.

Many different proposals were advanced to provide for a system of plant breeders' rights in the United States. Eventually, a proposed variety protection act was developed by the American Seed Trade Association and provided to a Federal-State Working Committee for review. Several changes were made in the proposed protection act on the basis of suggestions received from this working group^{5/}. In addition, the Seed Policy Subcommittee of the Experiment Station Committee on Organization of Policy took an active role in soliciting opinions from State Agricultural Experiment Station Directors and their staffs. This process was facilitated by four regional meetings held at University Park, Pennsylvania; Chicago, Illinois; Knoxville, Tennessee; and Salt Lake City, Utah; during the period from November 1968 through January 1969. The consensus developed from these regional meetings favored the establishment of a voluntary system for variety protection. It was hoped that the system would not restrict unduly the flow of germplasm, but was freely acknowledged that any effective system could diminish germplasm exchange.

Some significant provisions of the pending bill S.3070 are as follows:

1. Establishment in the Department of Agriculture of a bureau to be known as the Plant Variety Protection Office.
2. There shall be a Commissioner of Plant Variety Protection, one Assistant Commissioner, and an appropriate staff.

^{4/} White, Allenby L. The Effect of Breeders' Rights on the Seed Trade. Amer. Soc. Agron. Spec. Publ. 3. March 1964.

^{5/} Fortmann, H. R. Plant Variety Protection Legislation - The State-Federal Viewpoint. Proc. Fifteenth Ann. Farm Seed Conf., Kansas City, Mo. November 1969.

3. The Secretary will appoint a Plant Variety Protection Board. The Board shall consist of individuals who, as a group, are expert in various areas of varietal development covered by the Act. Membership on the Board will be drawn equally from the private and public sectors. This Board will advise the Commissioner on the adoption of rules and regulations and make advisory decisions on all appeals from the Examiner.

4. The term "novel variety" may be represented by, without limitation, seed, transplants, clones, and plants, and it is satisfied if there is: a) distinctness in the sense that the variety clearly differs by one or more identifiable morphological, physiological, or other characteristics, as to which a difference in genealogy may contribute evidence, from all prior varieties of public knowledge at the date of determination; b) uniformity in the sense that all variations are describable, predictable, and commercially acceptable; and c) stability in the sense that the variety may be sexually reproduced with its distinctive characteristics, with a reasonable degree of reliability, or to a degree comparable to that of other varieties of the same kind.

5. An application for a certificate recognizing plant variety rights shall contain: a) the name of the variety except that a temporary designation will suffice until the certificate is issued; b) a description of the variety setting forth its novelty and a description of the genealogy and breeding procedure, when known. The Commissioner may require amplification, including the submission of adequate photographs or drawings of plant specimens, if the description is not adequate or as complete as is reasonably possible.

6. It will be unlawful in the United States or in interstate or foreign commerce to sell by variety name seed not certified by an official seed certifying agency when it is a variety for which a certificate of plant variety protection specifies sale only as a class of certified seed.

Further points of interest include the following provisions: It does not represent an infringement of the Act for a person to save seed and to grow the resulting variety for his own use; the use and reproduction of a protected variety for plant breeding or other bona fide research shall not constitute an infringement of the protection provided under this Act; the terms of plant variety protection shall expire 17 years from the date of issue of the certificate in the United States; the proprietor will have the option to remedy by civil action an infringement of his plant variety protection (if variety is sold under the name of a proprietor's variety as shown on his certificate, there is a prima facie assumption that it is the same variety); and the burden of establishing invalidity of a plant variety protection shall rest on the party asserting invalidity.

Some observers have expressed concern over the fact that varieties will be registered on the basis of novelty alone. They argue that varieties should have merit, with merit defined as some redeemable characteristic displayed either in a specific environment or over a wide area. In these terms, merit could represent resistance or tolerance to a specific disease or insect pest, as well as specific physiological characteristics including the presence or

absence of some chemical constituent. The inclusion of merit in the registration of varieties would necessitate a degree of documentation that does not appear to be called for in proposed legislation.

Furthermore, the description and illustrations required to establish novelty may be of questionable value in the identification of certain crop varieties, especially varieties of cross-fertilized species. In the absence of appropriate field and greenhouse tests it may become virtually impossible, as the number of registered varieties increase, to state with certainty that a new variety does in fact differ from all existing varieties. As indicated, the Europeans have devised elaborate field tests to establish novelty claimed for varieties of self-pollinating species! If they encounter problems in distinguishing varieties of self-pollinated crops, and they do, then consider the problems that will be faced by plant protection Examiners who work solely from descriptions and pictures of both self- and cross-pollinated species.

The argument that breeders' rights will provide protection for germplasm is suspect. Apparently no questions would be asked if a plant breeder practices selection within a protected variety, produces some measure of change, and releases a new variety as a result of his efforts. It is obvious to all concerned that management during seed multiplication of varieties of the largely cross-pollinated species can result in significant changes in plant type. Thus, a seedling year harvest from a double-cut red clover variety can produce measurable changes in maturity. If the changes are documented and an incentive provided, a breeder could claim the production of a novel variety eligible for protection under the Act. In an extreme example, one could visualize selection within an outstanding protected variety that would not lead to any appreciable change in performance. A new variety could be claimed simply on the basis of novelty introduced by changing glume length or perhaps some other minor characteristic.

One is left with the impression that the proposed plant protection legislation is not designed primarily to protect germplasm, but, rather, to protect the names of varieties registered under the Act. The proprietor must determine whether or not there has been an infringement of the protection provided for his variety. It is doubtful if legal action would follow if a similar variety appeared on the market, provided there was a reasonable possibility that the varieties were not identical and the "new" variety is sold under a different name. Practical problems in establishing that two varieties are identical in all respects would serve as a strong deterrent to intemperate haste in claiming an act of piracy.

The Act also provides the originator with the option of specifying that seed of his variety must be certified in order to carry the varietal name. This is a sound procedure and one that will be welcomed in many quarters. Private plant breeders may specify that some of their varieties can only be marketed under a certification label. Presumably, they would take this approach in order to reduce the possibility of change during seed multiplication of protected varieties. Appreciable changes resulting from genetic shift could result in the loss of protection provided by the Act.

In spite of the Act's shortcomings, private breeders will gain a measure of protection that will be extremely valuable in the market place. Most, if not all private breeders, will attempt to develop varieties with merit even though merit is not a criterion for protection. In many crops they will take this approach to preserve their reputation as seedsmen and to meet competition. In all probability the pressure will be somewhat greater to produce varieties of merit in annual crops such as soybeans, cotton, wheat, etc., where comparisons are comparatively easy to make at harvest. The perennial forages present a more difficult picture because of the time and cost of establishing merit in species subjected to variable management practices.

Concern over high seed prices for protected varieties is probably exaggerated. In practice, exclusive protection will enable private breeders to distribute research costs over several years, thereby minimizing the premium that would otherwise have to be demanded during the immediate years following the release of a new variety^{6/}.

The prediction has been made that passage of the Plant Protection Act will be followed by a great upsurge in the development of privately financed plant breeding programs^{7/}. I suspect that the upsurge will be comparatively modest, with perhaps some strengthening in existing private plant breeding programs and a substantial growth in franchised seed production and franchised seed distribution. This assumption is based on the high cost of plant breeding and the time involved to realize a reasonable return on investment. There is no reason to doubt, however, that seed companies, either alone or in concert with other companies, will expand their commitments in plant breeding research.

The immediate effect of plant protection legislation on public plant breeding programs is difficult to assess. I corn can serve as an example, we can anticipate the maintenance of an appreciable public effort in the development of basic genetic information, in the isolation of pest-resistant germplasm, and in the release of improved inbred lines or germplasm for use by private breeders. A reduction in applied plant breeding by public agencies is a reasonable expectation, although this could be influenced by a number of variables, including: pressures to change current guidelines governing the exclusive release of public varieties through commercial companies; pressures from smaller seedsmen to maintain an alternative to the franchising of protected varieties; pressures from farm organizations to maintain one-variety areas in the interest of preserving overseas markets; and the obvious pressures that will arise if private breeding programs do not respond effectively to regional catastrophes caused by new diseases and insects or by new races of existing pests.

^{6/} Weiss, Martin G. Plant Breeders' Rights - Possible Impacts on Public and Private Breeding Programs in the United States. Forty-sixth Ann. Rept. Int. Crop Impr. Assoc. 1964.

^{7/} White, Allenby. Plant Variety Protection Legislation - What it Means to the Seedsmen. Proc. Fifteenth Ann. Farm Seed Conf., Kansas City, Mo. November 1969.

No one can predict the course that events will take following the eventual passage of a plant protection act. It is my guess, however, that public involvement in plant breeding will remain fairly high in the immediate future. The public effort in applied plant breeding will gradually decline, with public research in many crops attaining the balance that has been achieved in corn. In some lesser crops, public support may well decrease to the point where basic research is curtailed or eliminated along with applied plant breeding. If this were to happen, it could have a serious effect on the progress of private plant breeding programs and on the overall capability of American agriculture.

Crop improvement work in the United States is a tremendously large and complex undertaking with more than enough room for private and public research. Plant variety protection should help to strengthen the private sector, and one would hope that we would have the foresight to maintain a strong base for these programs within the public agencies.

Forage Crop Breeding in Arkansas

Marion S. Offutt
University of Arkansas

White lupine. Sweet (low alkaloid) winter hardy lines have been developed. Sources of marker genes and resistance to Phytophthora root rot are being sought by the irradiation of seed with gamma rays and neutrons. High yielding, bitter (high alkaloid), winterhardy white lupines are now being considered for release as a green manure crop. Results to date indicate that the alkaloid in the bitter white lupines may provide a measure of weed control for several weeks after the herbage has been worked into the soil.

Annual lespedeza. Marker genes developed by seed irradiation are being transferred into promising new lines of Korean lespedeza for positive varietal identification. Research at Fayetteville shows that there are significant differences in performance among commercial lots of Korean lespedeza seed obtained from 17 sources within seven states, which points up the importance of using only seed from germplasm of known performance.

Alfalfa. Progress has been made on the development of pasture-type alfalfa adapted to the upper South and lower Midwest. Objectives have been to develop types with broad, low crowns, the tendency to spread by means of creeping roots or rhizomes, a high leaf-stem ratio, and with as high a level of resistance to as many insects and diseases as possible. Phenotypic recurrent selection is being used to increase the level of resistance to Phytophthora root rot in a germplasm pool. Seed harvested from the third cycle of selection and used to establish plots indicate that significant progress has been made toward improvement for resistance to this disease.

Smooth bromegrass. Breeding efforts for this crop have been directed toward improvement in leafiness, disease resistance, and more rapid recovery after cutting. Results from performance trials indicate that two new experimental synthetics developed in this program are superior in the above respects to standard varieties included in the trials for comparison.

Forage Breeding Program in Louisiana

C. R. Owen
Louisiana State University

There have been no significant changes in forage breeding in Louisiana during the past 5 years. Included in the program are white clover, red clover, warm-season legumes, and dallisgrass. Emphasis on phases of the work has changed during this period.

White clover. Maintenance of clonal line components of Louisiana S-1 along with other lines considered as superior, the production of breeder seed of S-1, and supervising the production of foundation seed constitute the principal work with this species. A limited number of new combinations of clones are made and tested as superior clones are isolated.

Red clover. The development of a type or variety of red clover acclimated to the gulf coast area and resistant to powdery mildew has been the objective with red clover breeding. About 10 generations were given to acclimation. The clover was grown on a block of land and forced to reseed most years from the hard seed content. Powdery mildew resistance has been developed within the acclimated stocks by a modification of recurrent selection. Highly resistant lines were developed, and, after forage tests, the remnant seed of these lines were combined into a strain. Presently, evaluation tests with this strain are under way in Louisiana.

Dallisgrass. Collections of clones from naturally acclimated stands of grass have been compared for fertility of seed produced in the nursery at Baton Rouge. The more fertile clones are being grown in progeny rows. The objective of this observation is to isolate sexual types. It is believed that early in the breeding program with this grass such types were present.

Five lines of introductions from South America were obtained from Dr. Bashaw. These were classified as sexual types. The performance of these lines exhibited considerable variability in vegetative vigor and in fertility. The mean fertility of this material was less than that of strains developed at Baton Rouge from common dallisgrass.

Summer legumes. A summer legume species that may be grown in place of annual lespedeza is to be desired, especially in south Louisiana. Presently under observation are a number of species, the seed of which was supplied by Mr. Paul Henson and Dr. Ian Forbes. Included among these are species of Desmodium, Dolichos, and others.

Forage Breeding Research in Tennessee -- 1970

W. D. Barber
University of Tennessee

At the University of Tennessee the principle efforts in forage breeding are being devoted to orchardgrass, alfalfa, and red clover at the Knoxville campus, and to bermudagrass by Dr. B. N. Duck at U.T. Martin. The current status of these breeding efforts will be described by crop.

Orchardgrass (*Dactylis glomerata*). Several promising orchardgrass clones have been selected from local ecotypes and have been evaluated by Dr. Elmer Gray (now at Western Kentucky University). Final selections for experimental synthetic varieties are now being made. Major emphasis is being placed on good seasonal distribution of total production. At least one experimental synthetic will be made with clones selected for their ability to produce in hot summer months and one with clones which appear to be superior for cool season production.

Alfalfa (*Medicago* sp.). Several 16-chromosome *Medicagos* are being obtained from plant introductions and other breeders. These will be used in a breeding program with the ultimate objective of isolating resistance to the alfalfa weevil (*Hypera postica*). With the cooperation of Dr. B. V. Conger at the Oak Ridge National Laboratories, seed of selections and hybrids from these *Medicagos* will be irradiated, and the F₁ progeny will be screened for weevil-resistant mutants. The selections and the F₂ progeny of their hybrids will also be screened. Studies of self- and cross-compatibility among these *Medicagos* will be made in preliminary experiments.

Several varieties representing extremes in degree of winter hardiness are being compared in spring and fall plantings as a follow up to the observation that spring-seeded "nonhardy" alfalfas have overwintered satisfactorily and are still productive in their third year in west Tennessee.

Red clover (*Trifolium pratense*). Kentucky Synthetics A2 and A3 have shown good survival into the third and fourth production years in Tennessee. Selections now being made among surviving plants will be used in mass selection and hybridization efforts designed to develop a longer-lived variety for Tennessee.

Variety trials. Currently, variety trials are being conducted with alfalfa, orchardgrass, and red clover, and seed yield comparisons under different management situations are being made among annual lespedeza varieties.

Other species. Plans are being completed for an "observation garden" to include varieties and introductions of many forage grass and legume species. Breeding programs will be initiated with those species that show promise.

Bermudagrass (*Cynodon dactylon*). Some 560 plant introductions were obtained from the Regional Plant Introduction Station and from Dr. Wayne Huffine at Oklahoma State University. These introductions have been observed for two and, in many cases, three growing seasons and were visually evaluated for vigor, winter hardiness, forage production, seasonal distribution of forage, and disease resistance. Leading commercial varieties were also grown for

comparison. Many introductions have been discarded on the basis of little potential for forage production, but over 100 introductions are being maintained. Selections will be made this season for use in a hybridization program. Major emphasis will be placed upon winter hardiness, yield and seasonal distribution of yield, and forage quality as indicated by dry matter digestibility.

Forage Crop Breeding in Virginia - 1970

L. H. Taylor, G. R. Buss, and J. D. Miller
Virginia Polytechnic Institute

Orchardgrass. Research on methods of formulation of synthetic varieties is being continued. Single-cross data indicate that half-sib and full-sib progenies produce less forage than unrelated crosses. This data is largely from space-planted trials. A study is now underway to evaluate the performance of six different types of progenies at four spacings (10 cm, 20 cm, 30 cm, and 30 x 60 cm) to see if there is a significant spacing by type of progeny interaction.

Seed of two new orchardgrass varieties was produced in Virginia in 1970. Virginia 70 orchardgrass is the result of an attempt to preserve the desirable qualities of the naturalized strains of orchardgrass that have evolved in northern Virginia. Seed of nine farmer strains was blended together as source seed of Virginia 70. About 200 acres of seed certified as to origin were produced this year. Jackson orchardgrass is a 4-clone synthetic variety from our breeding program that has been evaluated in Virginia and elsewhere as Virginia 58-V-1. It is a week to 10 days later in heading than Virginia 70, and it may be useful as a companion grass with alfalfa and red clover for high quality hay production. Jackson has a vigorous, upright growth habit and good aftermath production, is resistant to leaf diseases, and is a good seed producer under Virginia conditions. Foundation seed was produced in 1969 and 1970, and the first acreage for the production of certified seed was planted in 1970.

Alfalfa. Five populations have been started for phenotypic recurrent selection including one composited from over 60 varieties, introductions, and experimental lines. Further field selection for weevil resistance is planned with Team.

A study on the inheritance of resistance to Southern anthracnose disease has been initiated using tetraploid and diploid sources of resistance. An inheritance study on yellow and white seedlings in diploid M. falcata is nearly completed.

An experiment with the varieties Team, Weevilchek, Williamsburg, Saranac, Narragansett, and Cherokee with 3 levels of weevil control (none, intermediate, complete) is being conducted. Team yielded best at all levels of control, and there was no significant variety x weevil control interaction at the first harvest.

Birdsfoot trefoil. A breeding program was initiated in 1957 with the objective of developing persistent trefoils with higher production and disease tolerance and which are suitable for pasture use. Spaced plants have been studied from many sources, with the better plants selected for polycross progeny evaluation. Ten synthetics have been constituted and tested rather widely. Results have been variable, but most synthetics were superior to standard varieties. Five groups of plants have been screened through three to five cycles of phenotypic recurrent selection with generally good results. Basic studies are being made on inheritance of various characters and also on cross compatibility and effect of backcrossing on growth type and other characters.

Crownvetch. Preliminary work was started in 1964 when about 1200 plants were evaluated. Superior clones were selected and evaluated subsequently in progeny tests. More recently, larger populations from a variety of sources were studied. All superior plants have been combined into two groups in a phenotypic recurrent selection program. Studies have been made on seed production as affected by clipping management.

SOUTHERN FORAGE PHYSIOLOGY AND ECOLOGY WORK GROUP

July 14, 1970

TOPIC: Present Status of Bermudagrass in the Region

Present Status of Bermudagrass in Alabama

C. C. King
Auburn University

Bermudagrass is grown on approximately 651,000 acres in Alabama. Percentage-wise, 53 percent of this acreage is Coastal and 46 percent is common. Midland and Coastcross-1 are planted on a very small scale--2,000 and 600 acres, respectively. Approximately 75 percent of the Coastal is used primarily for pasture and 25 percent is used for hay. None is presently being pelleted, and very little is ensiled.

The most active expansion of Coastal is now occurring in the Tennessee Valley area as a result of TVA's program of supplying sprigs for nursery-size plantings. Dr. D. A. Mays is responsible for this program.

We have recently revised our fertilizer recommendations for Coastal. For pasture, for a soil-testing medium in P and K, 60-40-40 is recommended before growth starts, and the nitrogen rate should be repeated one or more times when more growth is desired up to September 1. For hay, 400-50-100 is recommended, with the N to be applied in three or four applications.

Most of our present research effort with Coastal involves using it in one of several systems for grazing and/or hay production. One such test compares an intensive system of corn for silage and grain and soybeans for grain, followed by winter annual grasses and legumes with two extensive Coastal systems. These utilize Coastal alone and with crimson clover plus an allocation of fescue and Regal ladino clover. Another will compare Coastal with three varieties of sericea lespedeza. In others, we are attempting to extend the grazing season of Coastal by over-seeding it with Nova reseeding vetch, Yuchi arrowleaf clover, and rye. A beef cow-calf program is being used to evaluate these tests.

A plot-size experiment is being conducted on methods of preparing sod for establishment of Yuchi. Another involves ways to incorporate lime to overcome the acidifying effect of sulfur-coated urea applications.

A test which we have just completed compared Coastal bermudagrass with dallisgrass-white clover with varying size allocations of separately fenced areas of fescue. Another involved rates of N with and without winter legumes in perennial summer grasses (Coastal and bahia). Still another compared feeding confined cows with calves Coastal hay plus supplement, and sorghum silage plus supplement, with a conventional group on Coastal pasture in summer and Coastal hay in winter.

We have placed considerable effort on learning how to establish, fertilize, manage, and utilize this remarkable plant--Coastal. However, some untouched areas still remain. Some of our unanswered questions are how to maintain

Coastal stands on some of our heavier soils. Encroachment from other grasses, particularly common bermudagrass and bahiagrass, is also a problem with us. In the 1969-70 winter, we experienced enough winter kill on Coastcross-1 at Camden (west central Alabama) and at the Gulf Coast Substation to cause us to question whether it could be dependable forage for central and maybe even southern Alabama.

Present Status of Bermudagrass in Arkansas

A. E. Spooner
University of Arkansas

There are approximately 2 million acres of bermudagrass in Arkansas. It has been estimated that the 2 million acres are: 90 percent common, 8 percent Coastal, and 2 percent Midland. The acreages of each variety listed above are increasing each year. The regions of adaptation for these varieties are: Common, state wide; Coastal, southern two-thirds of the state; and Midland, northern one-half of the state. The seeding of common is not recommended in the extreme northern counties due to winter-kill.

Many problems have been encountered where bermudagrass is used for pasture. Some of these problems are: (1) lower average daily gains on highly fertilized pastures than on moderately fertilized pastures, (2) little or no gains during late July and August, and (3) maintaining a warm-season legume in the bermudagrass to increase forage quality. Our work indicates that the low daily gains obtained from highly fertilized bermudagrass is due to low intake rather than a decrease in the forage quality. The decrease in gains during late summer appears to be associated with the physiological maturity of the plant caused by long days, high temperatures, and low moisture. Annual lespedeza is the only warm-season legume available at present. We have not been able to maintain a stand in bermudagrass when moderate to high levels of fertilizer have been used.

Much of our research work at present is being devoted to the establishment and maintenance of tall fescue and white clover in bermudagrass sod. We have found that tall fescue and white clover can be successfully established and maintained in the bermuda sod provided that (1) the bermuda is grazed or mowed closely at seeding, (2) the fescue is seeded in 14- to 16-inch rows, (3) the white clover is seeded immediately following the seeding of the fescue, (4) proper fertilization practices are followed to favor the newly seeded species, and (5) limited grazing is practiced until the fescue and clover are well established. We have not had any difficulty in maintaining a balance of species after proper establishment.

We have recently completed a 6-year study on the feeding of grain to beef steers on a bermudagrass-white clover sod. The objectives of this study were (1) to determine if slaughter weight and grade could be obtained by this method and (2) to compare the results of this study with those obtained in the feed lot. We found that slaughter cattle can be successfully produced when fed grain on pasture, and there were no differences in gain or grade in the cattle produced by the two methods.

Status of Bermudagrass in Florida

D. W. Jones
University of Florida

Bermudagrass has been and continues to be an important forage plant on the well drained soils of northern and western Florida. On the poorly drained "flat-woods" soils of the peninsula portion of the State, pangola and bahiagrasses have been more productive than bermudagrass.

A statewide uniform forage variety trial was initiated in 1969 to test several of the newer forage grasses at different locations in the State. This work is in progress at Jay, Quincy, Gainesville, Ona, Ft. Pierce, and Belle Glade.

Additional trials involving bermudagrass and other grasses are being conducted at several locations in Florida. At Gainesville, Ruelke has in progress an experiment comparing 16 bermudagrass selections and/or introductions. At Ona, Hodges and McCaleb are comparing several bermudagrasses, pangolagrass, and bahiagrass in both clipping and grazing studies. Allen, at Belle Glade, is working with a number of grasses on organic soils.

Results of a study by Ruelke and Prine conducted on sandy soil at Gainesville showed Coastal bermudagrass to be the top producer when compared with five other bermudagrass hybrids (one was Coastcross-1), pangolagrass, and Pensacola bahiagrass. This was true at 120, 240, and 480 pounds of nitrogen per acre. At Ona on poorly drained soils in both clipping and grazing studies, Coastal bermudagrass was less productive than either pangolagrass or bahiagrass. In 1968 grazing studies involving three bermudagrasses were established at Ona; these included Coastcross-1, P.I. 224152, and P.I. 224566. They were grazed in 1969, and grazing is in progress at the present time.

From research results and farm observations, the following conclusions have been made regarding bermudagrass in Florida.

1. Coastal and Suwannee bermudagrass are best suited and most valuable on the well-drained soils of northern and western Florida.
2. Coastcross-1 establishes stands quicker than other bermudagrasses. It will grow on poorly drained soils and will tolerate flooding for short periods. Winter-kill is a problem, particularly on new plantings.
3. Several recent introductions have grown vigorously on both well and poorly drained locations and have exhibited some cold tolerance.

Current Status of Bermudagrass in Kentucky

T. H. Taylor
University of Kentucky

Forage crop workers at the University of Kentucky estimate that common bermudagrass may be found on 20,000 to 25,000 acres in Kentucky. This species is almost always an escape, and it is generally considered a "hated grass" or noxious weed by farmers. On the other hand, a Kentucky seed survey shows that, in the spring of 1970, 11 seed merchants out of 35 responding offered common bermudagrass seed for sale. Probably less than 1,000 acres are intentionally fertilized and managed as a forage crop. Bermudagrass is probably used more for turf than for forage in the state. Ironically, Kentucky grassland farmers badly need a high-producing warm-season perennial grass.

Experimental plantings of bermudagrass at Lexington have shown that Midland survives the winters while Coastal does not. The turf variety U-3 has been observed for the past 8 years on the Kentucky football field. Severe winter killing has occurred in the center of the field each year.

Bermudagrass turf types were evaluated over a 3-year period at Lexington. The strain Q17-Kansas was judged to be the best turf; Tifgreen, second; Sunturf, third; Royal Cape and Tiffine, fourth; while Tifway 1, Tifway 2, and Tiflawn were judged undesirable because of severe winter killing. Q17-Kansas was found to be quite winter hardy and very aggressive toward weeds; however, its texture is considerably coarser than that of other strains tested.

For the past 3 years Midland bermudagrass has been grown alone and in association with Balbo rye at Lexington. Bermudagrass made little growth from late September until early May. Rye sown into the sod in late September and dressed with 0, 33, 66, and 100 kg/ha of N produced, respectively, 1200, 1800, 2400, and 300 kg/ha of herbage from two harvests by the average date of May 7. The rye slightly suppressed the first bermudagrass crop, but it severely suppressed the winter and spring weeds. Growing rye in the sod did not increase seasonal production until 3000 kg/ha of N were applied annually. Herbage quality was estimated by the in vitro dry matter disappearance technique. Stage of rye maturity had a marked effect on nutritive value indexes (NVI) which varied from 62 to 74. On the other hand, NVI values for bermudagrass cut every 28 days varied among harvests from 40 to 43.

Midland bermudagrass was harvested at 5-, 7-, 14-, 21-, and 28-day intervals in a replicated trial in 1969. Harvesting frequency was much more important from the standpoint of quantity than quality of herbage produced. Seasonal yields varied from 4.8 to 12.7 tons/ha, while NVI values only varied from 42 to 47.

In another experiment, tall fescue and bermudagrass are being observed alone and in association under different N regimes.

From 1968 to the present our extension people have established 15 farmer demonstration plantings of Midland bermudagrass. Twelve counties are involved.

Status of Bermudagrass in Louisiana

C. L. Mondart, Jr.
Louisiana State University

Bermudagrass is the leading grass for improved pastures in Louisiana. It is used very extensively alone and in combination with various legumes for grazing. White clover is the legume most widely used in combination with bermudagrass. There are very few permanent pastures in Louisiana that do not contain some bermudagrass. In most areas of the state, if the land is plowed or disked and fertilized, bermudagrass will become established. Bermudagrass is also one of the major hay crops in Louisiana.

Relatively high levels of nitrogen are applied on Coastal bermudagrass for maximum yield and quality of hay. Nitrogen levels up to 400 pounds per acre are applied by some of the leading hay producers. Considerable acreage of common bermudagrass is harvested each year for hay, but usually this acreage receives less fertilization than the Coastal bermudagrass acreage.

In 1969, the Soil Conservation Service estimated the acreage of Coastal bermudagrass in Louisiana at approximately 100,000 acres. Most of this acreage is located in the northern part of the state. According to the SCS, Coastal bermudagrass acreage is increasing about 6,000 acres per year.

The most recent SCS inventory shows approximately 2.5 million acres of improved pastures in Louisiana. It is estimated that 1.5 million of this acreage is in common bermudagrass. This includes various mixtures of bermudagrass with other grasses such as dallisgrass and various legumes.

The acreage of Coastcross-1 bermudagrass in Louisiana is very small. Coastcross-1 is not recommended for planting in Louisiana primarily because of its lack of winter hardiness. It has difficulty surviving the winters as far south as Baton Rouge.

Disease and insect damage is not a major problem with bermudagrass in Louisiana. The two diseases most prevalent are Helminthosporium and Rhizoctonia.

Some of the current research projects with bermudagrass in Louisiana include:

1. Phosphorus and potassium studies on common bermudagrass.
2. Urea vs. ammonium nitrate as a source of nitrogen on Coastal and common bermudagrass.
3. Nitrogen fertilization studies on Coastal bermudagrass.
4. Chemical weed control studies on Coastal bermudagrass.
5. Grazing experiments comparing Coastal bermudagrass and common bermudagrass alone and in combination with Louisiana S-1 white clover.
6. A beef and hay production project to determine the maximum stocking rate for efficient utilization of Coastal bermudagrass in maintaining a beef-cow herd on a year-round basis.

The Status of Coastal Bermudagrass in Mississippi

Coleman Y. Ward and V. H. Watson
Mississippi State University

Coastal bermudagrass acreage has been increasing steadily in Mississippi over the past 10 years. The estimated acreage, based on surveys with county agricultural workers and estimates by the U.S. Crop Reporting Service, is 85,000 to 90,000. About 40 percent of this acreage has been planted since 1965.

About 60 percent of the Coastal bermudagrass in Mississippi is used for hay. The remainder is used for permanent pasture primarily for beef cattle. A small acreage is used as pasture for pigs and dairy cattle. The average size planting is 20 acres.

Coastal acreage should increase, especially as marginal lands exploited for soybeans during the past few years are returned to improved pastures.

Farmers in Mississippi are encouraged to plant Coastal bermudagrass on all new pasture areas. This recommendation is based on research data which show that Coastal out-yielded other warm-season grasses, especially during periods of low rainfall.

The distribution of Coastal acreage in Mississippi corresponds with the availability of nearby custom planters and enthusiastic local agricultural workers. There is little, if any, association of Coastal acreage with soils or geographical regions.

Status of Bermudagrass in North Carolina

W. W. Woodhouse, Jr.
North Carolina State University

Coastal is the only forage variety of bermudagrass being planted to any extent in this state. The acreage has been expanding steadily for the last several years, but we have no reliable estimates of total acres. It is widely used on the sandy soils of the Coastal Plain, and usage is spreading in the Central and Lower Piedmont on clays as well as sandy soils.

Recent research activity has included studies on establishment, management, and fertility. These have emphasized the need for care in handling and storage of stolons for planting, the importance of close grazing to maintain quality of forage, and the necessity for a balanced fertilizer program on Coastal.

However, the really dominating news on Coastal bermudagrass in North Carolina for 1969-70 was winterkilling. We experienced, for the state as a whole, what has been described as the coldest winter in 30 years. Cold damage on Coastal was widespread, with stand losses on some farmers' fields reaching essentially 100 percent.

Similar losses occurred on some of Dr. Chamblee's management plots and on certain treatments in two of my fertility experiments. While the farmers' experiences were not always easy to explain, cold damage on our research plots seemed to form a fairly clear pattern.

Severe killing occurred under either of two conditions: (1) where late cutting removed top growth and left stand exposed over winter (This was true even where clipping was done after frost, an insulation effect.), or (2) unbalanced fertilization such as inadequate K or excessive N coupled with late harvest. Where neither of these conditions applied, stands came through this severe winter in normal condition. Therefore, we feel that even these "30-year-winters" are not critical for Coastal in that portion of North Carolina where it is normally grown, under normal management and fertilization.

Status of Bermudagrass in Oklahoma

C. M. Taliaferro
Oklahoma State University

Bermudagrass has long been recognized by Oklahoma livestock producers as an outstanding pasture grass because of its high production potential and other good agronomic characteristics. Conservative estimates are that approximately 2.5 to 3 million acres of bermuda have been established in Oklahoma, and that figure grows yearly. Records of the Agricultural Stabilization and Conservation Service indicate that for the past 3 years (1967-69) more than 150,000 acres per year have been established in the state through the ACP cost share program. The majority of bermudagrass acreage established since the mid 1950's has been of the 'Midland' and 'Greenfield' varieties, with some plantings of 'Coastal' being made in the southeastern section of the state.

Much research has been conducted in Oklahoma on bermudagrass management and animal grazing performance. In general, returns from bermudagrass pasture have been a reflection of fertility amendments and management intensity. Good to excellent individual livestock gains can be obtained in the spring, but, characteristically, rate of gain declines substantially in the summer and fall months, apparently due in large measure to a reduction in forage quality. The inability of bermudagrass pasture to furnish forage of reasonably consistent and high quality across the growing season appears to be its greatest limitation.

Present Status of Bermudagrass in South Carolina

U. S. Jones
Clemson University

The estimated total bermudagrass acreage in South Carolina was about 495,000 acres in 1969. Some 84,000 acres were harvested for hay. A small amount was pelleted and ensiled.

About one-half of the bermudagrass is Coastal; the other one-half is Common. In South Carolina experiments, Common produces less total animal products per acre than Coastal but gives better average daily gains. Common appears to be slightly more palatable than Coastal.

Bermudagrass acreage has remained practically constant for the last few years. Reliable estimates indicate that acreage is indeed decreasing because of the labor shortage. Growers calculate they can put down more fertilizer and produce the same yield on fewer acres.

Coastal bermudagrass is superior to other perennial adapted summer-season grasses in yield, disease resistance, nematode resistance, drought resistance, frost tolerance, use of available water and nitrogen, root depth and distribution, rate of establishment, and potential for remaining weed-free.

Coastal produces higher yields of total digestible nutrients for grazing animals than other perennial grasses adapted to South Carolina. Beef cattlemen want another grass that can be grown on the same land along with Coastal and produce an amount of TDN during the 6 months from November to April equal to the Coastal bermudagrass production from May to October. Quite an order!

Coastal bermudagrass is the leading hay crop for South Carolina.

Good silage can be made from Coastal by adding preservatives or conditioners to the silage. However, dairymen do not prefer low-moisture Coastal bermudagrass silage (about 40 percent dry matter) being ensiled in conventional tower silos, particularly small ones. This does not preclude ensiling in sealed plastic or other gas-tight silos where the forage can be adequately preserved. Results indicated the relative milk production value was 88.6 percent when compared to corn silage.

Coastal is well adapted to nearly all areas of South Carolina on most soil types. An abundance of planting stock is available.

Coastal grows best at a pH of 6.0 to 6.5; when 448 kilograms per hectare (400 pounds per acre) of nitrogen are added and the grass cut for hay, about 2,000 kilograms per hectare (1,780 pounds per acre) of ground limestone is needed annually to maintain a suitable soil reaction.

Topseeding or sodseeding with winter annuals or perennials offer promise for improved palatability, yield, and profit from Coastal bermudagrass pastures for beef cattle.

Status of Bermudagrass in Tennessee

Henry A. Fribourg
University of Tennessee

Common bermudagrass is endemic to Tennessee, occurring throughout the state. It is found mostly in west Tennessee and the southern portions of middle Tennessee and east Tennessee. It is estimated to be present on about one million acres in the state and to be the predominant grass on about half of this acreage. In many pastures, particularly in west Tennessee, common bermudagrass occurs in association with tall fescue where the latter was originally established as an improved pasture.

Recent research with bermudagrass started in Tennessee in 1957. At that time a number of experiments was established at several locations to study the adaptation of Coastal and Midland and to measure the responses of these cultivars, as well as that of common bermudagrass, to rates of nitrogen fertilization. On the basis of these experiments and the observations made on a large number of trial plantings established by the Soil Conservation Service, it was determined that Midland was well adapted throughout the state at elevations up

to 1500 feet, whereas Coastal can be severely injured or killed in most of the state, except in the southern one-third of west Tennessee.

Midland bermudagrass has been recommended for hay and pasture in Tennessee since the mid-1960's. A vigorous program by Mr. Burns, Forage Extension Specialist, has created much interest in this grass. There are several certified sprig growers and about 4000 to 5000 acres in the state. Acreage has increased rapidly and should continue to do so. There are also about 1000 acres of Coastal in southern west Tennessee.

Dry matter yields of Midland have increased linearly with nitrogen fertilization up to about 400 kg/ha, but higher rates have not resulted in increased dry matter production. Over a period of several years, Midland was found to produce approximately 3 to 4 mt/ha without added nitrogen; this was doubled by adding 133 kg/ha and doubled again with 400 kg/ha. Only 2.5 mt/ha additional forage were produced by 800 over 400 kg/ha of nitrogen. In vitro digestibility of dry matter has been increased by about 10 percent as nitrogen fertilization ranged from 0 to 800 kg/ha; digestible dry matter production over the same range of nitrogen fertilization has ranged from 1.5 to 9.0 mt/ha.

A 3-year study in west Tennessee has shown that over-seeding of Midland or common bermudagrass sods with ryegrass, small grains, or tall fescue is both feasible and valuable. The season of production from bermudagrass sods was extended for several months. A majority of this additional forage was produced in March, April, and May and did not injure the stand nor reduce the production of the warm-season grass. The cool-season grasses contributed an additional 1 to 3 mt/ha. The tall fescue-bermudagrass combination, which has been observed for 5 years, appears promising.

A grazing experiment, involving Midland bermudagrass at several rates of nitrogen fertilization and common bermudagrass, has been initiated at Ames Plantation. Results forthcoming from this study will be of wide interest to Tennessee beef producers.

At Martin, Dr. Duck has initiated a program of bermudagrass improvement. Approximately 540 strains have been established and observed for several years. About 120 of these strains, which have exhibited desirable traits for forage production, turf use, winter hardiness, and other characteristics, have been selected for use in a program of varietal development and improvement.

Status of Bermudagrass in Texas

E. C. Holt and A. C. Novosad
Texas A&M University

Coastal is the predominant variety planted in Texas, and planted acreage has increased each year. The increase is not as rapid now as in previous years because some problems of low animal gains have been encountered in young grazing animals and because of recent interest in Coastcross-1. Extensive plantings of Coastal have developed in the central blacklands areas and have extended further westward into more arid sections than originally anticipated; it is being utilized in areas with less than 25 inches annual rainfall. Production problems have been encountered in the heavy soils of the blacklands and grand prairies. These problems consist primarily of limited yields and lack of response to fertilizers. Coastal is being used under a wide range of growing conditions, from very high production situations to limited fertilization, dryland conditions.

Coastcross-1 bermudagrass was planted widely in 1969, especially from central Texas to the Coastal Prairie. No estimate of planted acreage has been made. Extensive winter damage occurred in 1969-70, with plants being killed back to the original crown, especially in central Texas. The original plants survived in areas south of 32° latitude, and further reports may indicate survival north of this line. Stands were thin in early spring in many areas, and rate of recovery was dependent on fertilization. Difficulty in establishing Coastcross-1 was encountered in 1969 because of limited moisture during the planting season. Established stands of Coastcross-1 have indicated drought tolerance approximately equal to Coastal. Rapid growth when moisture is available for limited periods indicates adaptation to lower rainfall than might be expected.

Midland bermudagrass is utilized in the Panhandle where Coastal tends to winter-kill or where spring recovery of Coastal is slow. A few plantings of Selection No. 3 bermudagrass has been made in east Texas where its yield has been shown to be equal to Coastal.

Alicia bermudagrass, distributed by a private individual, has not been tested or observed by research personnel in Texas. No information on its adaptation or performance relative to other varieties is available.

Bermudagrass in Virginia

Harlan E. White
Virginia Polytechnic Institute

Since Virginia is in a transition zone for cool and warm season grasses, Virginia farmers have not utilized bermudagrass as widely as have some of their neighbors further south. However, on the Coastal Plains of eastern Virginia and the Southern Piedmont, Midland bermudagrass is well adapted and has real potential for production. It may also make a contribution on shallow, droughty soils of southwest Virginia. Coastal is limited to southeastern Virginia due to winter killing in other areas. In many instances, common bermudagrass also provides significant amounts of summer grazing.

Drs. Hallock, Brown, and Blaser, at the Holland Research Station in eastern Virginia, demonstrated the tremendous response of Midland and Coastal bermuda to nitrogen fertilization. Over a 4-year period, Midland averaged 6 tons of hay per acre; Coastal, 7 tons; and tall fescue, 3.5 tons, when 400 lb of nitrogen were applied per acre each year.

At the Middleburg Forage Research Station in the Northern Piedmont, Midland did not generally perform as well as the cool-season grasses for pasture. Bluegrass and orchardgrass tended to move into the bermuda and compete strongly.

Efforts have been made for several years to encourage farmers to make wider use of Midland and, in some cases, common for summer grazing, then overseed the stand with rye for winter grazing. This supplements the cool-season plants by extending the grazing season and reduces overgrazing of cool season pastures during the summer months.

Several factors have held back the wide acceptance of Midland. Areas where it is well adapted are not traditionally livestock-growing areas. Farmers still think of bermudagrass as "wiregrass" and a serious weed pest in cropland. Neither supplies of sprigs nor labor-reducing equipment for digging and springing have been readily available.

Progress is being made though. A source of certified sprigs of Midland bermuda has been developed at the Virginia Crop Improvement Farm. This year, for the first time, custom digging and planting equipment is available in the state. This is owned by the Piedmont Soil Conservation District and has been used to plant about 150 acres in 1- to 10-acre blocks. These plantings will serve as demonstrations and sources of sprigs for additional plantings.

The production potential of bermudagrass is being stressed in the Extension education program. Several test demonstrations with fertilization and overseeding of bermuda are in progress and are being watched with interest.

The Future of Bermudagrass in the South

Glenn W. Burton
USDA, ARS, CR, Tifton, Georgia

"You've Come a Long Way, Baby," title of a modern advertising song, summarizes quite well the status of bermudagrass in the South today. When the Southern Pasture and Forage workers met for the first time at Tifton, Georgia, in 1940, bermudagrass was the South's worst weed. Cotton was still king, but his army, made up of man-mule-plow units, often failed to control his worst enemy, bermudagrass. Common bermudagrass pastures, of which there were a considerable number, resulted when the army spent too much time in the shade.

In the late 1930's I soon learned that any reference to our bermudagrass breeding work would draw ridicule and criticism from a farm audience. A farmer, after looking over 147 different hybrids in test plots, left shaking his head because he was "afraid every one of them will grow on my farm." Three years later, the president of the Georgia Crop Improvement Association, who was successfully growing Coastal bermuda on his farm, refused to certify and sell sprigs because his "neighbors would run him out of the county." Surely no other forage species has had to overcome so much well-founded prejudice.

Today, bermudagrass is a highly respected forage grass, and as we contemplate its future we may well ask, "How did you get there, baby?" The answer would have to begin, "It wasn't easy." First of all, it took a better bermudagrass capable of producing twice as much dry matter in good seasons and six times as much during droughts. A much better variety with disease and nematode resistance, drought tolerance, high yield potential, great efficiency in growth-factor use, maximum dependability, ease of establishment, and reduced weed potential were required. One hybrid plant, Coastal bermudagrass, met these requirements and brought respectability to its kind. But not without a struggle. One of my bosses, seeing Coastal bermuda growing in a plot with no seedheads for the first time asked, "Will it produce seed?" When I replied, "No," he answered, "You might as well throw it away. A vegetatively propagated pasture grass hasn't a chance."

Coastal bermuda had good parents of diverse origin. But only a few of the 5,000 hybrids between these parents were outstanding. We took copious notes on those 5,000 spaced plants the first year, but had we used those notes to select the top 25 plants we would have missed Coastal. We measured rate of spread, dry matter yields, compatibility with annual lespedeza, sod density, disease resistance, etc. (over 50 observations in all), on triplicated plots of 147 of the best seedlings for 3 years before we selected the nine hybrids that included Coastal for palatability and frequent clipping studies. Additional testing, which included actual grazing trials, followed. The problems of vegetative propagation and the increase and distribution of pure stock had to be solved. Hundreds of questions pertaining to management asked by farmers and others were generally answered several years later from the results of carefully conducted experiments designed to supply the answers. Forage research workers in the South have spent well over a million dollars answering these questions. But the answers enabled men, like the late Hugh Woodle in

South Carolina, to convince Southern farmers that they could afford to plant some 10 million acres of Coastal bermuda. And those farmers who did so now realize well over \$200,000,000 more annually than they would had they planted common bermuda.

The future for bermudagrass is bright, if we continue to improve it genetically and use well-designed experiments to solve its problems and discover its merits. Only after a few farmers continued to doubt that you could burn Coastal bermuda sod without injuring it, did we design a well-replicated burning experiment to answer their doubts. Much to their surprise and ours, also, burning at the right time has increased dry matter yields over three-fourths ton per acre per year.

Recently, Marshall McCullough discovered that soybean millings contain a special fiber which, when heated in the pelleting process, will stimulate acetic acid production in the rumen. When this fiber was included in the dairy ration, milk production of a 15,000-pound herd was increased and feed costs reduced. Of many fiber sources tested by McCullough, only Coastal bermuda contained a similar fiber capable of this stimulation. As a consequence, Richard Feitshans has a new market for 85 percent of his 3,300-ton annual output of Coastal bermuda pellets. Coastal bermuda, the grass many have said, "won't produce milk," now becomes the grass that stimulates milk flow as none other, if you pelletize it.

Coastcross-1, a sterile F₁ hybrid between Coastal bermuda and an introduction from Kenya, has demonstrated that bermudagrass quality (IVDMD and animal gains) can be improved by breeding. Unfortunately, the highly digestible Kenya parents lack winterhardiness, and Coastcross-1 will suffer loss of stand at Tifton in severe winters. However, we now have two bermudas that I collected in Berlin and north Italy that have survived the winters well in northcentral Michigan. Crosses between these bermudas and a good Kenya introduction survived -4° temperatures without snow cover at Blairsville, Georgia, this past winter. Since these European bermudas also have good quality, we hope to have some high-quality hybrids soon that will be dependable throughout most of the Bermudagrass Belt.

The greatest threat to the future of bermudagrass in the South is bahiagrass, Paspalum notatum. Pensacola bahia has taken over many Coastal bermuda pastures, and I doubt that a good bermudagrass capable of resisting its inroads can be found. In much of the South, only an educational program designed to slow the movement of bahiagrass seed into bermudagrass pastures can save them. Once our soils become infested with Pensacola bahiagrass seeds, I doubt that bermudagrass or any other perennial pasture grass (except a better bahiagrass) will persist long enough to warrant planting them. The discovery of a selective herbicide could change the picture, but only if the new grass was enough better than bahia to pay for the cost of the herbicide and its application.

SOUTHERN FORAGE EXTENSION WORK GROUP

July 14, 1970

Joe D. Burns, Chairman

Evaluating Forage Varieties with Result Demonstrations

Harry W. Wellhausen
University of Arkansas

Many new forage variety introductions and other forage crops recommended for the first time need further observation and evaluation on a local level under a much wider range of conditions than in limited experiment station tests. Various cool season grasses and legumes recommended were prepared for 10 counties in 1969. These were as follows: Arrowleaf clover -- Amclo, Yuchi, and Meechee; Ball clover; reseeding crimson clover; white clover -- Regal, Ladino, Louisiana S-1, and Louisiana white; fescue -- Kentucky 31, Kenwell, and Fawn; ryegrass -- Gulf and Tetrablend 333. Sufficient seed was packaged for each demonstration at recommended rates of seeding. All legumes were inoculated and treated with molybdenum. All material and seed were supplied by the wholesale seed trade.

Each plot consisted of 1/10 acre and was seeded in strips 200' x 22'. All of the legumes were seeded in one direction perpendicular to the road fence, and the grasses were cross-seeded in the opposite direction. Most seedings were on a closely grazed bermuda sod after September 15 to October 15. Seed for each plot was mixed with about one gallon of sand at seeding and distributed by hand.

Seedbed preparation included light disking before or after seeding, depending on soil conditions, plus a drag or cultipacker, depending on equipment and soil conditions. Care was exercised not to cover seed too deep. Fertilization and lime were applied according to soil test prior to seedbed preparation. Total time for seeding, seedbed preparation, and fertilization by three people was 2 hours.

Where possible, the areas selected were along a roadside with the fields sloped so observations could be made from the road and variety labels tied to the fence. Heavy string or twine was used to mark the boundaries of each plot while seeding.

When the seedings were established, proper identification was placed on all of the plots as well as the demonstration. The county Extension staff made observations of the plots through the spring growth period as well as had scheduled study days for observing and discussing the research available on each forage variety.

The demonstration received publicity through county newspapers to advise farmers of the work as well as the location of the farms so that individuals could visit the demonstration when convenient.

Forage harvested was managed to permit reseeding. Some of the areas in large fields were fenced to permit management and reseeding. Plans were to use the demonstration for 2 to 3 years, depending on its continued value to the county. Seed for 10 more counties will be made available in the fall of 1970.

The North Carolina Forage Variety Testing Program

E. L. Kimbrough
North Carolina State University

Winter annual grasses, summer annual grasses, and perennial grasses and legumes were evaluated for yield, persistence, and other desirable characteristics at various locations within the state. Ryegrasses had higher total yields than oats, rye, wheat, and barley, with the major yield differences occurring in the spring harvests. The highest producing millet and sorghum-sudan hybrid produced from 4.0 to 5.8 as compared with 2.8 to 4.4 tons of dry matter per acre for sudangrass. Boone and Potomac were superior varieties of orchardgrass. Team alfalfa was equal in yield to standard varieties and showed some weevil resistance. Tillman ladino clover has yielded higher and shown better persistence than standard varieties.

Extension Forage Utilization Programs

W. E. Monroe
Louisiana State University

The beef cattle situation in Louisiana has created a need in the revision of the forage utilization program. The low calf crop percentage coupled with the light weight of calves at selling time has made beef cattle production on many farms unprofitable.

Major emphasis has been placed on the winter grazing program. Over-seeding permanent pastures and soybean fields with ryegrass has been found to be a more profitable way of wintering cattle than with hay. This also brings the animals into the breeding season in better health which is resulting in an increased percentage of calf crop.

Utilizing well fertilized winter pastures on a prepared seed bed is proving very profitable in carrying calves to heavier weights. Light weight calves are gaining 2 pounds daily on these pastures.

The 4-H winter grazing program is proving to be very profitable and is assisting in getting more farmers to accept this practice.

Involving Industry in Extension Programs

J. N. Pratt
Texas A&M University

Cooperative educational programs are most effective when goals are mutually beneficial to groups concerned. Extension forage programs in Texas have emphasized farm profit through intensive, efficient production and management practices.

High production of good-quality forage on low-fertility soils has required higher than traditional rates of plant nutrients. Realizing the potential for use of their products, the Texas Plant Food Educational Society and the Texas Agricultural Limestone Association have co-sponsored a limited number of Pilot Pasture Demonstrations with Extension. The basic principles of motivation have been used to enlist, maintain, and enlarge industry support: (1) recognition for their support on individual, company, and industry-wide bases; (2) responsibilities for funding the demonstrations; (3) potential growth and development of stable markets; and (4) accomplishments and success of the demonstrations.

Other industry groups can be successfully involved with county, state, and national Extension forage programs if: (1) goals are mutually beneficial, and (2) motivating factors are utilized.

North Carolina On-Farm Tests Prove That Pastures Are Profitable

S. H. Dobson, C. M. Reese, and D. G. Harwood
North Carolina State University

North Carolina on-farm tests prove that pastures and forages not only are profitable but that they can compete with corn and soybeans for land. Three years ago a series of on-farm tests involving forages and beef were started in the state involving the departments of Animal Husbandry, Farm Management, and Agronomy Extension. This is a report of one successful test where returns per acre of pastures and forages increased from \$12.50 in 1966 to \$44.62 in 1969. The farm has increased animal numbers by over 25% on the same acreage of land devoted to cattle and is now planning to allot more resources to forages and cattle. Increases in cattle prices account for only about 10% of the improved profit picture. Changes in his total forage systems and cattle management practices account for most of the improvement. The University Farm Records System has been used in the cost accounting and enterprise analyses.

Developing an Extension Winter Pasture Program

L. R. Allen
Clemson University

An Extension winter pasture program involves livestock producers and the people that provide them with services.

Knowledge gained from research and observations of experienced Extension workers goes into a regularly revised set of general recommendations. Many departments and disciplines are involved in making these recommendations.

In addition, we use special programs, such as our Forage Production and Management Contest which considers the total forage program on contestants' farms, to increase interest and encourage a two-way flow of information between forage researchers and specialists and our farmers.

South Carolina has considerable variation in soils and climatic patterns as do other Southeastern states. Allowances must be made for these differences in making recommendations and in the timing of them. In the Piedmont we can grow fescue. With a few exceptions we must depend on winter annuals in the Coastal Plain.

We feel that, for the most part, our general recommendations and releases provide our dairymen with the information they need. Most of them are using silage as their primary forage, with soilage crops next in importance. Hay and pasture play lesser roles. There is an exception to this in years when drought reduces supplies of stored forage. Then special winter pasture programs come into play.

The beef cattleman then is our prime target in a winter pasture program. Most of our beef gains are obtained during spring and summer. The winter program in cow-calf operations is designed to prevent the loss of what you have made in the summer and to provide areas resistant to trampling and suitable for calving and supplementary feeding. In stocker operations the winter program is designed to produce gains and improve market value of young animals.

In July we start talking and writing about our cool season Piedmont pastures. It pays to renovate on good land every 3 to 5 years. Decide where those new seedings will go, soil test, lime, fertilize, fallow, and plant fescue-clover at the time suggested for your area. On established fescue, soil test, lime, and fertilize during the last 2 weeks in August. Arrange for some demonstrations on this last point. Proper fertilization in August rarely fails to produce significant yields of fescue before winter sets in.

And finally, we keep a close watch on our late summer and fall pasture and forage crops. If we approach the fall season with poor pasture or low supplies of stored forage, we pull out all the stops, calling attention to the improved varieties on hand of small grains for quick fall pasture of spring growth for pasture, hay, or silage.

Uses For Result Demonstration Programs

Kelton Anderson
Mississippi State University

The result demonstration is one of the oldest methods used in educational programs to encourage farmers to adopt new practices. First, let's consider what a result demonstration is or does. It compares new varieties with old varieties, one herbicide with another for weed control, one insecticide with another for insect control, etc. Sometimes we compare new varieties or methods with other new varieties or methods. The over-all purpose of the result demonstration is to teach--showing results of these comparisons.

The main role of the result demonstration in modern agriculture is to introduce new practices or new enterprises into an area where they have not been used in the past. Emphasis in the South has been on somewhat neglected crops such as pastures, forage and feed crops, and introduction of new enterprises such as vegetable crops on small farms.

Where does the result demonstration fit? The often used simple result demonstration such as comparing two fertilizer rates on a certain crop doesn't give the impact that it once did. This is mainly due to the change in technology and the grasping for new information by farmers without having to personally see results of the demonstration.

How do we get maximum impact from result demonstrations? The following are some of the ways that result demonstrations have been traditionally used and a few new uses for them.

1. Tours and farm visits oriented around result demonstrations. It is important that the demonstrations be well marked by signs that identify the over-all demonstration and each treatment used. Site selection is most important. The demonstration should be located by a well-traveled road with easy access for people to stop and look.
2. The cooperator benefits most. He should be completely familiar with plans and objectives for the demonstration and have a written outline he can show to interested people. It is also most important that the cooperator actually help establish and conduct the demonstration.
3. The local agricultural worker (supervisor, county agent, or others) must carry the major responsibility, must show interest, be willing to collect data, help in summarizing the data, and use it in his educational programs (radio, television, farm meetings, news articles, etc.).
4. One special use that has been made in the Yellow Creek and Bear Creek areas of Northeast Mississippi has been to produce a slide story using an automatic projector with TV-like screen placed in local hospitals. Audience exposure and acceptance has been extremely good. Local result demonstrations are used in the tell-a-story sequence.

5 Industry people are asked to help supply materials for local demonstrations. They are included in tours and visits to the demonstrations so they can increase the spread of improved practices throughout the area in which they work. It is hard to beat a good testimonial.

6. A special in-depth training program called College of Agriculture for special enterprise studies has effectively used result demonstration data. The College of Agriculture included two sessions weekly for a period of four to five weeks, bringing in farmers with special interest in the enterprise discussed. Subject matter specialists from the University presented recommendations, and county agents used result demonstrations to support the specialists.

7. Possibly the best use of result demonstrations has been for training of agricultural advisors, both at the local and district levels. Subject matter specialists gain on-the-farm information by studying demonstration results.

In summary, result demonstrations have a definite place in our agricultural program. To be successful, result demonstrations must be problem oriented, well planned, located and conducted. Then the real test of their impact will be in the use of the demonstrations and the data collected from them. Planning, conducting, and utilization of the result demonstration are the keys to its effectiveness.

There's a lot of hard work involved in having a successful demonstration. We do not mind the hard work when we know that farmers learn more by seeing and doing than by just hearing.

Extension Program Ideas That Are Working

John R. Paulling
Federal Extension Service, Washington, D.C.

The individual's effectiveness in Extension teaching depends upon his ability to motivate people as well as his technical competence. To illustrate the view, the author describes a people-centered program, identifies techniques employed by Extension specialists in various States to support the county agent, and cites a sociological basis of motivation.

Organizing and Using a County Forage Council

Warren C. Thompson
University of Kentucky

1. The first step to organizing and using a County Forage Council is to get the full commitment from the County Agricultural Agent to a vigorous Forage Program. Be sure that he feels he is justified and is interested in establishing a high priority for forage production and use.
2. The state forage specialist must provide the County Agent with facts, including data on the conditions in the county and some rewarding changes that can be made to improve these conditions and increase income. These facts will be used by the Agent to visit with leaders informally and to be used at program planning sessions, especially the County Extension Council. Get a commitment from the County Extension Council that this is a high priority program and needs immediate and vigorous attention and that a County Forage Council needs to be formed to coordinate and help implement the program.
3. Agent needs to meet with the County Extension Council Chairman to get the appointment of the farmers on the Forage Council. Also needs to meet with finance groups (bankers, etc.) and other agri-business interests such as retail farm stores, fertilizer processors, machinery retailers, etc., to get them to select a representative (one from each interest area). The size of the Council will vary from one county to another; however, farmers who make their living farming should be in the majority. Some sample councils are: four farmers, one retail merchant, one banker, and one retail farm machinery dealer, or five farmers, two-agri-businessmen, one banker, and one other profession (veterinarian, farm service consultant, etc.)
4. County Agricultural Agent should meet with his counterparts in other agricultural agencies to explain his program and request their assistance toward implementation. These persons serve the Council and the program as resource people.
5. The County Agricultural Agent should establish meeting date, place, and agenda for the first meeting of the Forage Council. The state forage specialist is responsible for acquiring and presenting data including problems and potentials. The objective at this meeting is to establish program emphasis priorities to activate a sound program.
6. The implementation of the program is essentially up to the professionals--especially extension. Demonstrations (method and result) well located and based on fine research and of top priority problems are a must.
7. Hold training meetings and field days at the demonstrations. There should be at least three separate visits to result demonstrations the first year as soon as response is visible.
 - a) The Council needs to have first "crack" at the demonstrations. This is done to provide confidence and to give status to the group.

- b) All "professional recommenders" in agencies and agri-business.
 - c) The general public.
8. Keep an active program in communication (radio, newspapers, newsletters, and TV), meetings, and tours throughout the year, when applicable.
 9. Take stock of accomplishments and re-establish priorities at least on an annual basis.

The Kentucky Forage Council was organized in 1962. It is affiliated with the American Forage and Grasslands Council.

The Kentucky Forage Council has a general membership open to anyone interested in forage production and use. Its General Board of Directors is made up of a cross section of farmers (9), agri-business, college research and extension, county agents, and other agricultural agencies. The following is a list of the groups on this board:

9 farmers	Ky. Plant Food Association
Ky. Seed Dealers' Association	Ky. Crushed Stone Association
Farm Services	Farm Credit (Banks)
F.H.A.	Vo. Agr.
SCS	Ky. Retail Farm Equip. Dealers' Assoc.
Ky. County Agent's Assoc.	ASCS - ACP
Ky. Dept. of Agriculture	Extension Agronomy
Research Agronomy	Agronomy Dept.
Entomology Dept.	Agr. Engineering Dept.
Agr. Economics Dept.	Dairy Dept.
Animal Science (Beef) Dept.	Radio
TV	Newspapers

The President of the Council is always a farming farmer. The Executive Board of Directors is composed of six farmers, two businessmen, one researcher, one state extension specialist, and one county agent.

Two events are sponsored by this group annually. In January the Grasslands Conference is held at the University. Attendance is acquired by invitation only. Our prime audience is the "professional recommenders" and about 100 top innovator farmers. This meeting is not used as a substitute for any county meetings, but rather to supplement them and provide subject matter information that will make local meetings more meaningful. Also, this meeting serves as a nerve center for problems that need answering by research that are forage-animal oriented.

A second event is the mid-June Grasslands Field Day and Tour. The prime objective here is to show program adaption and the results farmers are receiving from applying research on a whole farm basis.

Training Sessions For Hay Quality

A. C. Novosad
Texas A&M University

Hay is recognized as an important crop in Texas with an annual value in excess of \$90 million, ranking fourth among the major crops. It has also been recognized that the quality of hay produced and fed varies tremendously, and that low-quality hay is not an economical source of nutrients for many classes of livestock. Too often, hay has been produced or purchased and fed with little regard for its feeding value.

County agricultural agents and others realized that educational programs designed to bring about an improvement in hay quality would increase the profits of livestock producers and make a significant contribution to the agricultural economy. Much of the educational effort in this regard is being directed through the medium of county hay shows. These events are supplying the spark needed to arouse interest in forage quality improvement. The shows are providing the opportunity for teaching the value of quality, how to recognize it, and how to produce quality hay. Popularity of the shows is reflected in their growth from 15 held in 1962 to 52 in 1969.

It has been demonstrated that the hay shows provide an excellent opportunity to focus attention at one time on all of the important factors involved in the production and utilization of high-quality forage. Producers enter samples of hay in the show and these are judged and classified on the basis of a score card which considers both the physical and chemical characteristics of the hay. A ribbon is awarded each entry based on the judges' scores.

Although the ribbon awards, and sometimes other awards, are important in stimulating interest and participation, these are not given great emphasis. Major emphasis is placed on the educational aspects. A hay show without a program where information can be presented to producers is of questionable educational value. The educational program varies somewhat in format, but includes the judge's discussion of the hay entries and his reasons for the classification scores given to representative samples. Production and harvesting factors affecting hay quality are emphasized. The effect of hay quality on animal performance is pointed out, as well as the value and profitability of producing and utilizing high-quality hay. The value of forage testing also receives emphasis.

This relatively simple educational approach has had a significant effect in increasing the hay quality in the state. It has been effective in teaching the value of high-quality hay and has built buyer resistance to low-quality hay. As with any other activity, successful hay shows don't "just happen." They require involvement of local people and other sponsoring groups, proper planning, and attention to all details.

Forage In-Service Training

Harlan E. White
Virginia Polytechnic Institute

Extension Agents have varied backgrounds--Animal Science, Dairy Science, Horticulture, Economics, etc. It is difficult to give these individuals adequate training to enable them to advise farmers on forage production and utilization. Realistically, we do not expect to make them experts, but we do want them to have adequate background to discuss forage problems with farmers.

At V.P.I., our Extension Annual Plan of Work is built around "Industry" committees. The Forage Committee is composed of Extension Specialists from several subject matter areas, including Animal Science, Dairy Science, Agricultural Engineering, Agricultural Economics, Soil Fertility, Entomology, Plant Pathology, and Weed Control.

Our forage in-service training is planned and conducted by this unit. In the past, training has been given in alternate years. In 1966, 4 days of training were conducted in the early winter at three locations with 70 Extension Agents attending. In 1968, 4 days of training were presented to 24 Extension Agents at the Continuing Education Center in Blacksburg. This was planned primarily for new agents and those who had not attended previous sessions.

The format for each of these sessions was essentially the same. The first day was spent on economics, variety selection, physiology of plants as related to management, soil fertility, and weed and insect control. The second day was used for discussions of disease control, efficient use of equipment for harvesting, storing, and feeding forages, and forage testing procedures. On the third day, use of forage test results in formulating dairy rations was covered in detail, including the economics involved in feeding least-cost rations. The final day was devoted to using forage test results in formulating beef cattle rations, a discussion of planning and conducting forage programs in the county, and an evaluation of the 4-day session by the participants.

These sessions have generally been well received by the agents. The primary complaint, and this is well justified, is that too much material is covered in the time allotted.

We have not had the privilege of selecting Extension Agents to attend the training. Consequently, many of those who would benefit most have not been present. Others were present who are already doing a good job and did not really need to be there.

This year the Forage Industry Committee does not plan to conduct forage in-service training. We have proposed that forage training sessions be held in each of the six Extension Districts in Virginia. Essentially the same type of material will be presented as before, with less emphasis on formulating rations. Extension Agents are encouraged to attend and invite top livestock farmers and dairymen from their county to attend with them. This will enable both progressive farmers and Extension Agents to benefit from the material and will encourage closer agent-farmer working relationships. Our better farmers are entirely capable of absorbing the material and add welcome dimensions to discussions.

Tropical Grasses Have Great Production Potential as Cattle Feed

Jose E. Muriente
University of Puerto Rico

There is a great potential for forage and, hence, for cattle production in vast areas of the Humid Tropics with year-round warm weather, rainfall of 50 to 120 inches per year, and deep porous soils. Under these conditions, dry matter yields of selected tropical grasses adequately cultivated have increased from about 5,000 pounds per acre of poor-quality herbage produced by unimproved volunteer pastures to about 40,000 pounds (130 tons green) of excellent-quality forage in Puerto Rico.

The work of our Experiment Station and the Agricultural Research Service Projects have demonstrated that when high-yielding, nutritious grasses with heavy fertilization, liming, weed control, good rotation, intensive systems of utilization, and careful management, good quality forage is available the year around. Our techniques are applicable to similar tropical areas around the world.

Several basic practices are necessary for high yields of good quality forage grasses. These include good soil preparation, planting an adequate pasture variety, having a pH not lower than 5.8, and applying enough complete fertilizer.

The grasses with the highest production and quality are:

1. Napiergrass - Pennisetum purpureum
2. Guineagrass - common Panicum maximum
3. Guineagrass - coarse Panicum maximum
4. Pangolagrass - common Digitaria decumbens
5. African stargrass - Cynodon plectostachyus
6. Paragrass - Panicum purpurascens
7. Caribgrass - Eriochloa polystachya

The highest producer of green forage by cutting when 35 to 65 days old is Merkeron napiergrass which, with the application of 2 tons of fertilizer, has produced over 130 tons of green forage per acre yearly.

The high production of selected grasses which is given by high fertilization and appropriate harvesting methods demonstrates the great goals toward which progressive farmers with adequate financing may look in beef and milk production in the tropics.

Our goals now are to induce our cattle farmers in rainy regions or where there is irrigation to lime efficiently and apply up to a ton of complete fertilizer when grazing beef cattle or raising heifers.

We in Puerto Rico will push the new findings of our researchers through result demonstrations and field trials.

I think the date is near when, with enough water, we can produce with grasses over 1,400 pounds of beef and over 7,000 quarts of milk per acre yearly.

Team Approach in a Forage-Beef Cattle-Dairy Extension Program

O. N. Andrews
Auburn University

The team approach has been used quite extensively by the Auburn University Extension Agronomist and other specialists in related fields in forage-beef cattle and dairy educational programs.

County Extension programs and annual plans of work are made on a commodity basis. Cattlemen and dairymen have active county and state associations. The team approach of specialists is one method used to effectively meet the needs of cattlemen and dairymen and to assist county Extension workers in their work with these commodity groups and individuals. Extension and experiment station specialists in agronomy, animal science, dairy science, agricultural engineering, veterinary medicine, farm management, and marketing work together in planning and conducting meetings, tours, demonstrations, and publications. The number of specialists participating in these activities varies.

Below are some of the team approach activities, which include forage production and utilization:

--Two or more area beef cattle short courses, one night per week for 6 weeks, were held in each of the four Extension districts in 1967. Attendance totaled 1400 cattlemen for the 2-hour sessions on forage production.

--A state-wide beef cattle short course was held in Auburn in 1968. One-half day was devoted to feed production. The Extension Agronomist served as chairman of the team of agronomists and beef cattle specialists in planning this program. Proceedings were published.

--In 1968, 10 specialists of the Cooperative Extension Service wrote Extension Circular "A-01," Alabama Beef Cow-Calf Production, an 86-page publication. It included one chapter on forage production written by O. N. Andrews, Extension Agronomist. Seventeen thousand copies were printed and distributed.

--Seven one-day area silage production, harvesting, storage, and utilization meetings were held in February 1969. The team was composed of four Extension specialists--agronomist, beef cattle nutritionist, dairyman, and agricultural engineer. Proceedings were mimeographed and distributed to the 425 silage growers and others attending.

The Extension Agronomist and other Extension specialists assist county Extension workers with 15 to 20 county beef cattle or dairy short courses and tours each year.

Renovation Demonstrations Using Animals

Joe D. Burns
University of Tennessee

Renovation in Tennessee is the putting of clovers back in all-grass pastures. Our objective has been to demonstrate the value of renovation in terms of beef and milk per acre. Naturally, all other recommended practices were included, with renovation being the focal point. Cows and calves, steers, and dairy cows have been used in different renovation demonstrations. These demonstrations have been conducted by the county Extension staffs, assisted by the Extension Animal Husbandry and Agronomy Departments with excellent local cooperation.

Some of the problems have been:

1. Farmers and other professional workers wanting to stock the renovated pasture and non-renovated pasture at the same rate when the renovated pasture was producing considerably more forage.
2. The people involved not wanting to stock heavily enough, leaving too much feed on the pasture; it gets tough and crowds the clover.
3. The normal problems of obtaining adequate weighing and handling facilities and uniform cattle.

Observations:

1. With cow-calf herd, no measurable difference in quality was observed between fescue-lespedeza pasture vs. fescue-Ladino-red-lespedeza pasture.
2. A quality difference was measured with steers and dairy cows. Clover-fescue gave higher daily gains and milk production than fescue alone.
3. The greatest difference between renovated and non-renovated pastures is in production of feed per acre in a cow-calf program.

Rewards:

1. More beef, milk, and profit per acre.
2. More interest in pastures.
3. A better understanding of the feed needs of cow-calf, steer, and dairy operations.

White County Renovation Demonstration Information

18 acres fescue - renovated - March 1968

18 acres fescue - non-renovated, not fertilized

Average Daily Gain - Calves (lb per day)

	<u>Non-renovated</u>	<u>Renovated</u>
1968	1.52	1.72
1969	1.78	1.72

Stocking Rate (Acres per cow)

<u>Non-renovated</u>	<u>Renovated</u>
1.6	1.4
2.0	1.2

Average Return Per Acre Above Renovation Costs (30¢ beef)

<u>Non-renovated</u>	<u>Renovated</u>	<u>Difference</u>
\$42.90	\$58.30	\$15.40

Pounds of Beef Per Acre (2 yr. average)

<u>Non-renovated</u>	<u>Renovated</u>
153	241

REGISTRATION LIST - 1970

<u>Name</u>	<u>State</u>	<u>Address</u>
Eyles, Alan G.	AUSTRALIA	Brisbane, Queensland
Andrews, Olin N.	Alabama	Auburn
Berry, Charles D.	"	"
Evans, E. M.	"	"
King, C. Cooper, Jr.	"	"
Little, Joe A.	"	"
Mays, David A.	"	Muscle Shoals
Rollins, Gilbert H.	"	Auburn
Spooner, A. E.	Arkansas	Fayetteville
Wellhausen, Harry W.	"	Little Rock
Johnson, I. J.	California	Woodland
Hanns, Wayne W.	Florida	Gainesville
Hodges, Elver M.	"	Wauchula
Johnson, James T.	"	Gainesville
Jones, D. W.	"	"
Moore, John E.	"	"
McCaleb, John E.	"	Wauchula
Prine, Gordon M.	"	Gainesville
Quintero, A. H.	"	"
Ruelke, O. Charles	"	"
Smith, Rex L.	"	"
Wallace, A. T.	"	"
Wing, J. M.	"	"
Beaty, E. R.	Georgia	Athens
Brown, Broadus	"	"
Brown, R. H.	"	"
Burdick, Donald	"	"
Burton, Glenn W.	"	Tifton
Cummins, D. G.	"	Athens
Dobson, J. W.	"	Blairsville
Eberhardt, L. W.	"	Athens
Flatt, W. P.	"	"
Forbes, Ian, Jr.	"	Tifton
Johnson, J. R.	"	Athens
King, Frank	"	"
Langdale, Noah	"	Atlanta
Lowrey, R. S.	"	Athens
Monson, Warren G.	"	Tifton
McCullough, M. E.	"	Experiment
Nash, James N.	"	Athens
Powell, J. B.	"	Tifton

NameStateAddress

Powell, John D.	Georgia, continued	Americus
Rogers, T. H.	"	Athens
Sell, O. E.	"	Experiment
Smart, W. G., Jr.	"	Griffin
Stuedemann, John A.	"	Watkinsville
Wells, Homer D.	"	Tifton
Wilkinson, S. R.	"	Athens
Wilson, Clarence M.	"	Atlanta
Heath, Maurice E.	Indiana	Lafayette
Buckner, Robert C.	Kentucky	Lexington
Bush, L. P.	"	"
Sigafus, Roy E.	"	"
Taylor, T. H.	"	"
Thomas, Grant W.	"	"
Thompson, Warren C.	"	"
Webster, G. T.	"	"
Wyles, J. W.	"	"
Allen, Marvin	Louisiana	Franklinton
Ellzey, H. D.	"	"
Hembry, F. Glen	"	Baton Rouge
Mondart, C. L., Jr.	"	"
Monroe, W. E.	"	"
Morgan, N. D.	"	Shreveport
Owen, C. R.	"	Baton Rouge
Hanson, A. A.	Maryland	Beltsville
Hart, Richard H.	"	"
Leffel, Robert C.	"	"
Anderson, Kelton	Mississippi	State College
Bennett, Hugh W.	"	"
Burson, Byron L.	"	"
Dillard, James G.	"	Starkville
Edwards, Ned C., Jr.	"	Raymond
Lusk, John W.	"	Starkville
Palmertree, Hiram D.	"	State College
Ward, Coleman Y.	"	"
Watson, Vance H.	"	"
Cope, Will A.	North Carolina	Raleigh
Dobson, S. H.	"	"
Kimbrough, Lamar	"	"
Lucas, H. L.	"	"
Timothy, David H.	"	"
Woodhouse, W. W.	"	"

<u>Name</u>	<u>State</u>	<u>Address</u>
McCroskey, John	Oklahoma	Stillwater
Taliaferro, C. M.	"	"
Arroyo-Aguilu, Jose	PUERTO RICO	Rio Piedras
Caro -Costas, R.	"	"
Valez-Fortuno, J.	"	"
Lopez-Matos, L.	"	"
Muriente, Jose E.	"	"
Perez-Sosa, Ramon	"	Mayaguez
Sotomayor-Rios, A.	"	Corozal
Allen, Leonard R.	South Carolina	Clemson
Gibson, Pryce B.	"	"
Williams, John N., II	"	"
Burns, Joe D.	Tennessee	Knoxville
Montgomery, Monty J.	"	"
Reynolds, John H.	"	"
Anderson, Warren B.	Texas	College Station
Bashaw, E. C.	"	"
Lancaster, J. Albert	"	Kilgore
Lippke, Hagen	"	Angleton
Novosad, A. C.	"	College Station
Pratt, J. Neal	"	"
Riewe, Marvin E.	"	Angleton
Lewis, W. W.	Virginia	Blacksburg
Miller, John D.	"	"
Taylor, Lincoln H.	"	"
White, Harlan E.	"	"
Paulling, J. R.	Washington, D. C.	
Smith, Richard E.	Wisconsin	Madison

